PROCEEDINGS OF THE 30TH AND 31ST SOUTHERN PASTURE AND FORAGE CROP IMPROVEMENT CONFERENCES

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REPORT FROM S-45 TO SPFCIC ON THE PRESENT STATUS OF THE S-45 PROJECT.

The title of the project is "Relationship between properties of southern forages and animal response." There are two facets to the project: 1) Animal response and 2) forage properties. It is scheduled to terminate June 30, 1975. The animal response data are complete at this time. These data include voluntary intake, average daily gain, feed conversion ratio and nutrient digestibility. Six animals have been used to determine these responses on each of the forages harvested. In addition, certain amino acid absorption data are being obtained at Kentucky on a selected number of samples. Forages were produced and fed at nine locations from Puerto Rico to Kentucky and Beltsville, Maryland to Texas. The total cuttings equal 76. This is a considerable number of forages for which intake and gain data have been obtained with cattle. This number exceeds that specified in the project outline. The forages include 25 cuttings of warm-season perennial grasses including bermuda, bahia, Pangola and Star. There are also 27 cuttings of cool-season perennials including orchardgrass and fescue. In addition, there are 16 cuttings of sorghum-sudan hybrids and six of alfalfa. These cuttings have come from different states and from different stages of maturity. They were fed as hay under controlled conditions as specified in the project.

For determination of forage properties in the laboratory, there are 104 total samples since some of the forage cuttings were fed at two locations. There are two or more laboratories analyzing for each property. These properties include proximate analyses. Van Soest fiber analysis, nylon bag and *in vitro* digestion, fatty acids and oils, amino acids and minerals. All the laboratory analyses are to be completed by October 15, 1974. These data will then be recorded and coded according to the format of the International Feed Composition project with the cooperation of Dr. Lorin Harris of Utah State. After the data are recorded and the cards punched, statistical analysis will be conducted by Dr. H. L. Lucas of North Carolina. We anticipate having a preliminary report by May, 1975, with final report by December 31, 1975.

The results of this project should provide an increased knowledge of those properties of southern forages which control or limit the utilization of those forages by animals. Certainly, improved utilization is an integral part of a program to improve pasture and forage crops in the South. In addition, we anticipate that the project will suggest improved methods for the prediction of forage quality in the laboratory, espcially the prediction of intake. Such methods will be of value to the forage production scientist since it is, after all, intake or voluntary consumption that in large part controls forage utilization by animals. Until final results of our project are known, we suggest and encourage the use of *in vitro* digestion in screening forage crops for quality just as we have for the past several years.

Finally, during our discussion yesterday we came to realize just how important our project really is. Dr. Lucas suggested that we include the following statement in reference to the relevance of the S-45 project in the world of today and tomorrow, and we do so with tongue-in-cheek. "Our expectation is to exploit fully the yield potential of forage crops and to optimize the level of animal production for maximum profit. Enhanced rural development and highly favorable export and trade balance are obvious nontrival spinoff". It is difficult to be more relevant than that.

By: John E. Moore
Chairman, S-45

PRODUCTIVITY AND MANAGEMENT STUDIES WITH NEW TROPICAL GRASSES [1/]

By A. Sotomayor-Rios [2/]

SUMMARY

There is a great potential for grass land farming in the humid Tropics with year-round warm weather, high rainfall, and deep porous soils.

Selected forages such as star, napier, pangola, congo, and others under intensive management produce excellent yields when 1 ton of 15:5:10 fertilizer is applied per acre yearly. One ton of limestone containing magnesium should be applied for every ton of fertilizer. Under cutting management, it is profitable to apply up to 2 tons of 15:5:10 fertilizer per acre yearly to napier (Merker) and about 1 1/2 tons for most other grasses.

Under intensive management in the humid tropics, a good pasture should carry about two 600-pound animals or one mature cow throughout the year and should produce about 1,000 pounds of beef per acre yearly. A cow on a good pasture should produce over 6,000 pounds of milk yearly, without needing concentrate feeds.

There are many forage grasses with tremendous potential which must still be evaluated under cutting or grazing management. Higher yields per acre can be expected in the future, with new and superior breeds and grass species interacting with proper management factors under humid tropical conditions.

INTRODUCTION

Millions of unproductive acres of mountainous lands in the Tropics require the protection against erosion which grasses can afford. How effective well-managed grasses can be in comparison with other crops in the control of soil losses from a typical deep, red Ultisol on 40-percent slopes with about 80 inches of annual rainfall is shown in the following tabulation taken from the work of Smith and Abruña (17).[3/]

Cover	Annual soil loss (tons/acre)
Fallow	126.0
Rotation (sweetpotatoes, corn, etc.)	17.5
Sugarcane	7.5
Grass	1.2

1/ Appreciation is expressed to J. Vicente-Chandler for his help and data provided in the preparation of this paper.

2/ Research geneticist, Mayaguez Institute of Tropical Agriculture, Agricultural Research Service, U.S. Department of Agriculture, Mayaguez, P.R. 00708.

3/ Underlined numbers in parentheses refer to items in "Literature Cited" at the end of this paper.

Heavy fertilization is required for efficient grassland or livestock production in the humid Tropics since most of the soils in this area are low in nutrients. The investment in fertilizers requires intensive grassland management to assure efficient use of the forage produced.

Average monthly rainfall and temperatures under typical conditions in the humid region of Puerto Rico at Corozal are shown in figure 1. The lowest temperatures normally occur from December through April with maximum temperatures from June to September. As shown in figure 1, monthly rainfall at Corozal ranged during the last 10 years from an average of 3.71 inches during February to 8.95 during October.

The deep, red acid Ultisols on which most of the experiments were conducted had a pH of about 4.8 with 12 milligrams equivalent of exchangeable bases per 100 grams of soil. Organic matter content average 3.4 percent. Clay minerals were predominantly kaolinitic with high free iron and aluminum oxide contents (33, 34).

Tropical Grass Species Most Widely Used

The most important tropical forage grass species are: napier or elephant (*Pennisetum purpureum* Schum), guinea (*Panicum maximum* Jacq.), pangola (*Digitaria decumbens* Stent), para (*Panicum purpurascens* Raddi), Carib (*Eriochloa polystachya* H. B. K.), molasses (*Melinis minutiflora* Beauv.), star (*Cynodon nlemfuensis* var. *nlemfuensis*), signal (*Brachiaria brizantha* Stapf), Congo (*Brachiaria ruziziensis* Germain C. Evrard), tanner (*Brachiaria mutica* Forsk Stapf) and buffel (*Cenchrus ciliaris*).

Napier or elephant is a tall, erect, high-yielding grass which is propagated by stem cuttings. In Puerto Rico the 'Merker' variety is used because of its resistance to an eyespot caused by *Helminthosporium sacchari*. Excellent yields of over 100 tons of green forage per acre have been reported in Puerto Rico with this grass, which is adapted to both grazing and cutting (3, 7, 9).

Guinea is a high-yielding grass which is propagated by clumps or seed. The most important factor limiting the propagation of this grass is the low viability of its seed. In Puerto Rico there are many guineagrass varieties (18, 43). Of these, 'Common' is the most widely used. A guineagrass selection (USDA PI 259553) has been reported to yield over 47,000 pounds of dry forage per acre yearly in Puerto Rico when properly fertilized and irrigated (18). This selection is being evaluated at Corozal, P.R. under grazing management with excellent results. The seed of 'Guinea' USDA PI 259553 has been found to be superior to that obtained with the 'Common' variety.[4/]

Pangola is a vigorous grass which spreads by stolons and is propagated entirely by stem cuttings. A large number of species of *Digitaria*, mostly from the Oakes collection (15), have been evaluated in Puerto Rico under cutting management. One selection of *D. eriantha* has been reported to yield over 40,000 pounds of dry forage per acre yearly at Rio Piedras (24). Other promising *Digitaria* selections are *D. milanjiana*, *D. setivalva*, and *D. decumbens* (20, 24). At Corozal, *D. pentzii* (USDA PI 299752) has produced excellent yields under cutting management, proving superior to Pangola.

4/ Velez-Santiago, J. "Effecto de Niveles de Abono y Densidades Poblacionales en la Produccion de Cariopsides (semilla) en la Yerba Guinea, *Panicum maximum* Jacq." MS Thesis. University of Puerto Rico, Department of Agronomy, Mayaguez, July, 1972.

Para and Carib grasses often grow together. These grasses are very vigorous and are propagated by stolons; they form a heavy cover in a relatively short time. Once these grasses invade a pangola pasture, they are difficult to eradicate.

Molasses grass is a low-yielding species producing abundant viable seed. When ungrazed, it is very aggressive, particularly on infertile soils. The acreage of this grass in Puerto Rico is small compared to the other grasses.

Stargrass is an excellent forage which is propagated entirely by stem cuttings. This grass flowers abundantly but does not produce viable seed in Puerto Rico. This species was known as *C. plectostachyus* and was later reclassified as *C. nlemfuensis* var. *nlemfuensis* based on cytological and taxonomic evidence (23). Stargrass has been extensively planted in Puerto Rico and the Caribbean area and is one of the outstanding forages at present in this region (5, 6).

Signalgrass is a vigorous, hairy, stoloniferous forage which is established by stem cutting. This grass produces little viable seed (24) but gives high forage yields under both grazing and cutting management. A glabrous *B. brizantha* resembling signalgrass has been reported (19) to produce over 39,000 pounds of dry matter in Puerto Rico when cut every 60 days and receiving adequate fertilizer and irrigation.

Congograss is a high-yielding forage which is propagated by seed and stem cuttings. This species is very similar to signalgrass, except that it produces light green, broader leaves. Both signalgrass and Congograss are resistant to most pests and diseases. Tannergrass is a very vigorous grower with glabrous succulent leaves. It is propagated by stem cuttings. Congo, signal, and tanner grasses have been described in Puerto Rico by Sotomayor-Rios et al. (22, 25).

Buffelgrass produces erect or prostrate stems. It is propagated by seed and grows well in dry areas. This grass is economically important in the semi-arid southern part of Puerto Rico.

Insects and diseases of tropical grasses

The most important insect pest attacking Pangola and other *Digitaria* species is the yellow sugarcane aphid, *Sipha flava*. Damage by this insect is especially high during the cool dry months. Efforts have been made to select *Digitaria* species with resistance to the attacks of the yellow sugarcane aphid (24). Scale insects and mealybugs also attack pangolagrass pastures.

The chinchbug *Blissus leucopterus* attacks all tropical grasses and is especially harmful to guineagrass and pangolagrass. The fall army worm, *Spodoptera frugiperda*, and the grassworm, *Mocis repanda*, attack all the grasses during the wet season. Stargrass has been observed under attack by the larva of the moth *Marasmia similia* (19). Leafhopper also attack grasses, but cause little damage. The lesser cornstalk borer *Elasmopalus lignosellus*, has occasionally been observed attacking pangolagrass.

The most important diseases affecting guineagrass in Puerto Rico are ergot caused by *Claviceps maximemsis*, black linear leafspot caused by *Phyllosticta* panici, and a leafspot caused by *Cercospora fusimaculans* (27). Napier (elephant) grass is severly attacked by the fungus *Helminthosporium sacchari* which causes extensive eyespot lesions on leaves and stems. A rust, *Uromyces leptodermus*, attacks Carib grass, causing minor defoliation of the lower leaves during dry periods.

Inflorescence blight affecting a napiergrass X Cattle millet hybrid is caused by *Ephelis trinitensis* (*Balansia claviceps*) and has been reported to

occur in Puerto Rico (28). This disease may appear on other grasses as well.

Liu (13) in Puerto Rico reported that the rust which affects pangolagrass and other *Digitaria* spp. is caused by a variant of *Puccinia oahuensis*. He identified it as *P. oahuensis* var. *Digitaria decumbensis*.

Fertilizer for Cut Grasses

High quantities of nutrients are removed from soil by grasses in the Tropics, as shown by Vicente-Chandler (31). Table 1 shows that well-fertilized cut grasses growing on a typical Ultisol in the humid mountainous area of Puerto Rico removed, on the average, enough nitrogen, phophorus, potassium, calcium, and magnesium per acre yearly to equal the N, P2O5, and K2O in 1 ton of 15:5:10 fertilizer.

Based on a series of experiments conducted on several soils in Puerto Rico, Vicente-Chandler et al. (33, 34) have shown that grasses receiving no fertilizer obtained an average of 108 pounds of nitrogen from the soil per acre yearly. Since about 300 pounds of nitrogen fertilizer can be removed per acre yearly by grasses, as shown in table 1, it follows that about 200 pounds or more of the nitrogen required by grasses must come from fertilizer. Approximately half of the nitrogen applied as fertilizer is lost by leaching or volatilization. Therefore, if high yields of grasses are desired, about 400 pounds or more of nitrogen must be applied per acre yearly to grasses which will be cut.

TABLE 1.--Nutrients absorbed by grasses harvested by cutting at Orocovis, P.R.[1]
(Pounds)

Grass	Yields of dry forage/ acre/ year	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
Napier------	25,200	302	64	504	96	63
Guinea------	23,000	288	44	363	149	99
Pangola-----	23,700	299	47	358	109	67
Para--------	24,000	307	43	383	115	79
Congo-------	29,900	305	49	402	137	70
Star--------	25,300	346	58	419	135	48
Molasses----	13,200	207	32	208	56	44
Average	23,470	293	48	377	114	67

1/ Fertilized with 400 pounds of nitrogen, 65 of phosphorus, and 400 of potassium per acre yearly in 6 equal applications; soil limed to pH 6.0 and grasses cut every 60 days. Reprinted by permission of the authors; based in part on "The intensive management of tropical forages in Puerto Rico," Univ. P.R. Agric. Exp. Stn. Bull. 187. 1964.

The effect of nitrogen fertilization on yields and composition of grasses harvested by cutting has been determined in numerous experiments of several years' duration by Vicente-Chandler et al. (35-37), Caro-Costas et al. (5, 8), and Abruna et al. (1) in Puerto Rico. These researchers have found that under humid tropical conditions in Puerto Rico, grasses such as guinea, pangola, star, Congo, and Carib, when harvest by cutting, respond strongly in yield and

protein content to applications of 400 pounds or more of nitrogen per acre yearly, while napier or 'Merker' responds strongly up to the 800-pound rate. Molasses grass responds only up to the 200-pound rate. The nitrogen should be applied after each curring to obtain these results. The grasses respond more strongly in yield to nitrogen fertilization as the cutting interval is increased and during seasons of flush growth than during winter months of slow growth.

Vicente-Chandler et al. (33, 34) have shown that most soils in Puerto Rico supply large and widely varying quantities of potasssium to the grass during the first two years of cropping, but by the third and fourth years their potassium supply becomes rather stable, averaging about 100 pounds per acre yearly. As was shown in table 1, grasses can take in about 400 pounds of potassium per acre yearly. However, part of this represents luxury consumption, and actual requirements of the grass may be approximately 300 pounds. Considering that about one-fourth of the potassium applied as fertilizer is lost, about 300 to 400 pounds of potassium should be applied per acre yearly to sustain high yields of cut grasses in the humid region.

The effects of rates of application of potassium fertilizer on yields and composition of grasses growing on three Ultisols in Puerto Rico were determined by Vicente-Chandler et al. (38). These authors concluded that:

1. Grasses such as napier, guinea, para, pangola, and star, when harvested by cutting, generally respond to applications of about 300 to 400 pounds of potassium per acre yearly. On soils which have considerable available potassium, lighter applications may be used until these reserves are depleted.
2. Potassium chloride and potassium sulfate are equally efficient sources of potassium.
3. Soils should be limed properly to assure high yields and effective use of potassium fertilizer.
4. A potassium content of less than 1.0 to 1.5 percent in 60-day-old grass suggests a deficiency of this nutrient.
5. Smaller applications of potassium at planting and after each cutting, instead of application of total allotment at planting, help to prevent luxury consumption by the first growth.

The effect of phosphorus fertilization on yield and composition of grasses growing for periods of 2 to 4 years on three typical Ultisols of the humid region in Puerto Rico with all other nutrients provided in abundance were determined by Figarella et al. (12). Rates ranging from 0 to 130 pounds of phosphorus (300 pounds of phosphoric acid) per acre yearly in one application were tested. These authors concluded that:

1. Grasses harvested by cutting respond strongly to applications of about 65 pounds of phosphorus (150 pounds of phosphoric acid) per acre yearly on soils with little or no previous fertilization with this nutrient.
2. A phosphorus content of less than 0.17 percent in 60-day-old grass indicates a deficiency of this nutrient.
3. Phosphorus need be applied only once yearly since it is strongly secured in the soil against leaching, and there is little luxury consumption of this nutrient by grasses.

As was shown previously, grasses harvested by cutting and growing in the humid region with all other nutrients provided in abundance respond strongly in yield to applications of 400 pounds or more of nitrogen, 150 of phosphoric acid, and about 300 pounds or more of potash (a source of potassium) per acre yearly. This suggests that a 3:1:2 or similar fertilizer ratio (15:5:10, for example) is well suited for grasses grown under similar conditions. This ratio may vary according to results of plant analyses.

Vicente-Chandler et al. (33, 34) have shown that the application to napiergrass of 2 tons per acre yearly of 15:5:10 fertilizer worth $160 produces an increase of 21,000 pounds of dry forage, which is worth $357, for a profit of $197 per acre yearly. This is assuming that the price of a 15:5:10 fertilizer is about 4 cents per pound, including cost of application and limestone required to neutralize the acid content, and that dry forage in the rumen is worth 1.74 cents per pound. Vicente-Chandler et al. (33, 34) have also shown that it is profitable to apply up to 1 1/2 tons of 15:5:10 fertilizer per acre yearly to the other grasses studied. Fertilizer should be distributed in about 6 applications yearly, one after each cutting, and 1 ton of limestone should be applied for each ton of fertilizer used.

Other Factors Affecting Yield

Frequency of harvesting. The effects of cutting intervals, varying from 30 to 90 days, on the yield of tropical grasses have been studied in Puerto Rico by Vicente-Chandler et al. (36, 39, 41), Caro-Costas et al. (5, 8), and Sotomayor-Rios et al. (20, 24, 26). These researchers found that the dry forage yields produced by grasses increase with length of cutting interval. However, the forage became less nutritious with age. Protein and phosphorus content in all cases, and magnesium and calcium content in most cases, decreased with increasing length of cutting interval. The decrease with age in the nutritive value of tall grasses such as napier ('Merker') or guinea is primarily attributed to an increase in the proportion of stems, which are less palatable and nutritious than leaves. The leaf-to-stem ratio of other grasses such as pangola, congo, and tanner do not vary markedly among ages from 30 to 90 days according to Vicente-Chandler (33, 34). Their decrease in nutritive value as the cutting interval increases results from a decrease in the nutritive value of both leaves and stems.

The productivity of 19 forage grasses belonging to the three genera *Brachiaria*, *Cynodon*, and *Digitaria* was studied on an Ultisol during a period of 2 years by Sotomayor-Rios et al. (26). Three hybrids using *D. decumbens*, *D. smutsii*, and *D. milanjiana* as parental material were tested, among others (table 2). The yields per acre yearly of the 19 grasses are shown in figures 2 to 4. Table 3 shows the average yields and crude protein and dry matter content of the 19 forage grasses using three harvest intervals. On an Oxisol at Isabela, P.R., the average dry matter yields of 10 grasses (table 4, figure 5) cut at the same intervals were much higher.

A compromise must be reached between the high yields produced with a long harvest interval and the better quality resulting from frequent harvesting. Based on the findings of McDonald (14), the digestibility of grasses decreases 0.48 percent per day of increase in cutting interval. In this way grasses cut at 30-, 40-, 60-, and 90-day intervals should be about 71, 66, 56, and 42 percent digestible, respectively.

TABLE 2.--Nineteen forage grasses evaluated at Corozal, P.R., and their plant introduction numbers1/

Grass number	Species field identification	Plant identification number1/		Other name for species
		USDA PI	PR PI	
1	Brachiaria brizantha----------------	--	1525	Signal (hairy)
2	---------do-------------------------	--	5567	
3	Brachiaria ruziziensis--------------	247404	5366	Congo
4	Brachiaria mutica-------------------	299499	6451	Tanner
5	Brachiaria brizantha----------------	255346	5909	Signal (glabrous)
6	---------do-------------------------	--	5569	
7	Digitaria pentzii X D. smutsii------	--	9621	U.F. 382/
8	Brachiaria decumbens----------------	210724	5365	
9	Digitaria setivalva-----------------	299892	6402	
10	Digitaria pentzii X D. milanjiana---	--	9619	U.F. 59-12/
11	Digitaria decumbens-----------------	--	5124	A-24
12	Brachiaria sp.----------------------	299497	9626	
13	Cynodon nlemfuensis var. nlemfuensis	--	2341	Star
14	Digitaria milanjiana----------------	299731	6416	
15	Digitaria decumbens-----------------	299752	6439	Transvala digitgrass
16	Digitaria smutsii-------------------	299828	6434	
17	Digitaria pentzii X D. pentzii------	--	9620	U.F. 42-12/
18	Digitaria decumbens-----------------	111110	--	Pangola
19	Brachiaria decumbens----------------	--	9625	

1/ U. S. Department of Agriculture and Agricultural Experiment Station, University of Puerto Rico, plant introduction number.

2/ University of Florida number.

TABLE 3.--Average yields and average crude protein and dry matter content of 19 forage grasses at 3 intervals during a 2-year period at Corozal, P.R.1/

Cutting intervals in days	Yields of green forage (lbs/acre/yr)	Yields of dry forage (lbs/acre/yr)	Dry matter (pct)	Crude protein (pct)	Yields of crude protein (lbs/acre/yr)
60	77,328a	19,694a	26.46a	9.21c	1,511b
45	70,078b	16,773b	25.32b	10.54b	1,620a
30	60,590c	13,381c	24.54c	13.15a	1,629a

1/ Means followed by the same letter are not significantly different at the 0.05 level of probability.

TABLE 4.--Identification of 10 forage grasses evaluated at Isabela, P.R. and their plant introduction number

Grass number	Grass species	Plant introduction number[1/] USDA PI	PR PI	Other name for species
1	*Brachiaria mutica* (Forsk) Stapf.--	299499	6451	Tanner
2	*Digitaria decumbens* Stent.--------	111110	--	Pangola
3	*Brachiaria ruziziensis* (Germain C. Evrard)--------	247404	5366	Congo
4	*Brachiaria brizantha* Stapf.-------	--	1525	Signal
5	*Cynodon nlemfuensis* var. *nlemfuensis*--------	--	2341	Star
6	*Cynodon dactylon*-----------------	288218	8991	Var. *coursii*
7	*Digitaria decumbens* Stent.--------	--	9477	Hexapangola
8	*Digitaria smutsii* Stent.----------	299828	6434	
9	*Digitaria decumbens* Stent.--------	299752	6439	Transvala digitgrass
10	*Digitaria eriantha* Steud.---------	--	5277	

1/ Plant introduction number from U. S. Department of Agricultural Experiment Station, University of Puerto Rico, Mayaguez 00708.

The following tabulation taken from the work of Vicente-Chandler et al. (unpublished data) shows the close agreement between percent digestibility of stargrass calculated as recommended by McDonald (14) and in vitro digestibility determined by the method of Van Soest et al. (29) and Deinum and Van Soest (11).

Age of grass in days	Percent of digestibility of stargrass: McDonald method	Van Soest method
30----------------------------	70	70
45----------------------------	63	66
60----------------------------	56	59
90----------------------------	42	51

Coward-Lord et al. (10) determined the chemical composition and in vitro digestibility of 10 tropical forage grasses in Puerto Rico when cut at intervals of 30 to 180 days. The in vitro digestibility of the 10 grasses decreased with age from an average of 60 percent for the 30-day interval to about 44 percent at 180 days.

Vicente-Chandler et al. (32, 33) have concluded that for optimum production of nutritious forage, grasses should be cut about every 45 days during season of flush growth and every 60 days during the rest of the year.

Height of cutting. Variations in yield caused by various heights of grasses at cutting in species such as napier, star, Congo, pangola, hexapangola, and others have been studied in Puerto Rico by Vicente-Chandler et al. (39), Caro-Costas et al. (5) and Sotomayor-Rios et al. (21). These researchers have found that higher yields of dry forage are obtained with low cutting than with high cutting with few exceptions. Molasses grass yields are severly reduced

by close cutting, while those of guineagrass are not affected by cutting heights, although a better stand and faster recovery result from high cutting. Cutting height had no effect on the crude protein yield of the grasses.

Frequency and height of grazing. The effects of two grazing heights and three grazing intervals on yields of star and pangola grasses were studied at Corozal in the humid region by Vicente-Chandler et al. (42). The grasses received 1 ton of 15:5:10 fertilizer per acre yearly. The forage actually consumed by the grazing animals was determined by the difference method. When the grasses were grazed down to within about 6 inches of the ground, higher yields were observed than with close grazing, as is shown in table 5. The higher yields of the grasses with high grazing can be attributed to the greater photosynthetic area remaining after grazing.

TABLE 5.--Effects of two grazing heights and three grazing intervals on the productivity of a pangolagrass pasture in the humid region 1/
(Pounds)

Grazing interval in days	Dry forage consumed/acre/year by grazing cattle		
	High grazing 1/	Low grazing 2/	Average
14	14,271	11,009	12,646
21	13,152	9,984	11,568
28	11,866	8,037	9,951
Average	13,096	9,677	--

1/ Forage grazed to about 6 inches.
2/ Forage grazed to about 2 inches.
Source: 42.

Season of the year. Lower rainfall, shorter days, and cooler weather from December to April are the most important factors responsible for the low yields produced by grasses during this season (33, 34). Sotomayor-Rios et al. (26) found at Corozal that the lowest dry forage yields of 19 grasses occurred in this period. No significant correlation was obtained between total rainfall, percentage of crude protein, and dry forage yield of the 19 grasses. A positive significant correlation was obtained between dry forage yield and temperature while a negative significant correlation was obtained between temperature and crude protein content (figs. 6-11).

Grass Pastures

Fertilization. About half as much forage and therefore much less nutrients are taken from the soil under grazing as under cutting management. For this reason, fertilizer requirements of pastures differ from those of cut grasses. Although there is a heavy return of nutrients under grazing management (A mature cow produces in the feces yearly about 157 pounds of nitrogen, 40 of phosphoric acid, and 128 of potash), there is poor distribution of them on the pasture (16). When nitrogen is applied in such heavy concentrations on limited areas, heavy leaching losses occur. However, phosphorus and potassium fertility can be built up in pastures under heavy stocking and intensive management as has been shown by Vicente-Chandler et al. (30, 32), since these

nutrients are more strongly held in the soil than is nitrogen.

Productivity under grazing. Caro-Costas et al. (9) compared the productivity of guinea, pangola, napier, para, and molasses grasses in a 4-year grazing experiment in the humid region of Puerto Rico (table 6). With the exceptions of para and molasses grass, the other species carried at least 2 heads per acre. The cattle grazing on guinea, napier, and pangola grasses gained an average of 1.3 pounds per head daily. These gains are considered good for young animals fed exclusively on grass pastures.

TABLE 6.--Productivity of well-fertilized[1/] pastures of five grasses on steep slopes over a 4-year period at Orocovis, P.R.

Grass	Weight gains/ acre/ year (pounds)	Average daily gain/ head (pounds)	Total digestible nutrients consumed/ acre/year[2/] (pounds)	Carrying capacity in 600-pound animals/ acre[3/]	Minimum heads carried/ acre
Guinea	1,178	1.3	7,983	2.6	2.0
Napier	991	1.3	7,268	2.3	2.0
Pangola	1,004	1.3	7,425	2.4	2.0
Para	697	1.1	5,745	1.8	1.3
Molasses	575	1.0	4,320	1.4	1.3

1/ 1 ton of 14:4:10 per acre yearly in 4 equal applications.
2/ Calculated from body weights, cow-days per acre, and gains in weight.
3/ 600-lb. animal making normal gains=8.5 pounds total digestible nutrients consumed daily.
Source: 9.

The productivities of star and pangolagrass pastures were compared in the humid mountains of Puerto Rico over a 2-year period by Caro-Costas et al. (6). Stargrass produced 1,350 pounds of gain in weight per acre yearly compared to 947 pounds for pangolagrass. Average daily gains per head were 1.3 and 1.1 pounds for star and pangolagrass, respectively (table 7).

TABLE 7.--Productivity of intensively managed star and pangolagrass pastures over 2 consecutive years of grazing at Orocovis, P. R.

Grass	Weight gains/ acre/ year (pounds)	Average daily gain/ head (pounds)	Total digestible nutrients consumed/ acre/year[1/] (pounds)	Carrying capacity in 600-pound animals/ acre[2/]	Minimum heads carried/ acre
Star	1,350	1.3	9,260	3.0	2.5
Pangola	947	1.1	8,030	2.5	2.0
LSD					
0.05 level	257	.2	869	.3	---

1/ Calculated from body weights, cow-days per acre, and gains in weight.
2/ 600-pound animal making normal gains=8.5 pounds total digestible nutrients consumed daily.
Source: 6.

The productivity of Congo, star, and pangolagrass pastures was determined at Orocovis in the humid mountains of Puerto Rico by Vicente-Chandler et al. (unpublished data). Stargrass produced the highest weight gains (table 8). Congo and pangolagrass yields were similar. Average daily gains per head for tested cattle were 1.3 pounds for stargrass and 1.1 pounds for the other grasses.

TABLE 8.--Productivity of well fertilized[1/] pastures of congo, star, and pangola grasses at Orocovis, P.R.

Grass	Weight gains/ acre/ year (pounds)	Average daily gain/ head (pounds)	Total digestible nutrients consumed/ acre/year[2/] (pounds)	Carrying capacity in 600-pound animals/ acre[3/]	Dry forage consumed/ acre/year[3/] (pounds)	Apparent percentage of digestibility of forage consumed[4/]
Star	1,274	1.3	9,008	2.9	16,040	56.2
Congo	845	1.0	6,715	2.2	11,960	56.2
Pangola	913	1.1	6,996	2.3	13,680	51.1

1/ One ton of 15:5:10 per acre yearly in 4 equal applications.
2/ Calculated from body weight, cow-days per acre, and gains in weight.
3/ One 600 pound animal making normal gains=8.5 pounds total digestible nutrients consumed daily.
4/ (Total digestible nutrients ÷ dry forage) X 100.
Source: Vicente-Chandler, J., et al. 1974. Univ. P.R. Agric. Exp. Stn.

Five grasses are being evaluated on an Ultisol at Corozal by Sotomayor-Rios and others (unpublished data). The grass species are tanner, *Brachiaria mutica* (USDA PI 299499); *Digitaria milanjiana* (USDA PI 299731); guinea, *Panicum maximum* (USDA PI 259553); signal, *Brachiaria brizantha*; and pangola, *Digitaria decumbens*. A minimum of two heads per acre are grazed on the pastures at all times. Results for 1 year of grazing show that the grasses produced weight gains which ranged from 821 to 754 pounds per acre yearly (table 9).

TABLE 9.--Productivity of five intensively managed grasses over a 1-year period at Corozal, P.R.

Grass	Weight gains/ acre/year (pounds)	Average daily gains/ head (pounds)	Tester daily gain/head (pounds)
B. mutica	754.25	1.03	1.06
D. milanjiana	806.75	1.08	1.11
P. maximum	821.25	.99	1.03
D. decumbens	776.75	1.02	1.01
B. brizantha	786.00	.93	.99

Milk with grass rations. On an all-grass ration from steep pastures of tropical grasses (pangola, napier, and guinea), Caro-Costas and Vicente-Chandler (2), reported that eight cows produced an average of 6,064 pounds of milk (25.2 pounds or 11.5 liters daily) over an 8-month lactation period. Butterfat content of the milk averaged 3.8 percent. The data these authors provided suggest also that the use of concentrate feed can be sharply reduced by using well-fertilized pastures, and that on good pastures little or no concentrate feed should be required for the first 10 liters or so of milk produced.

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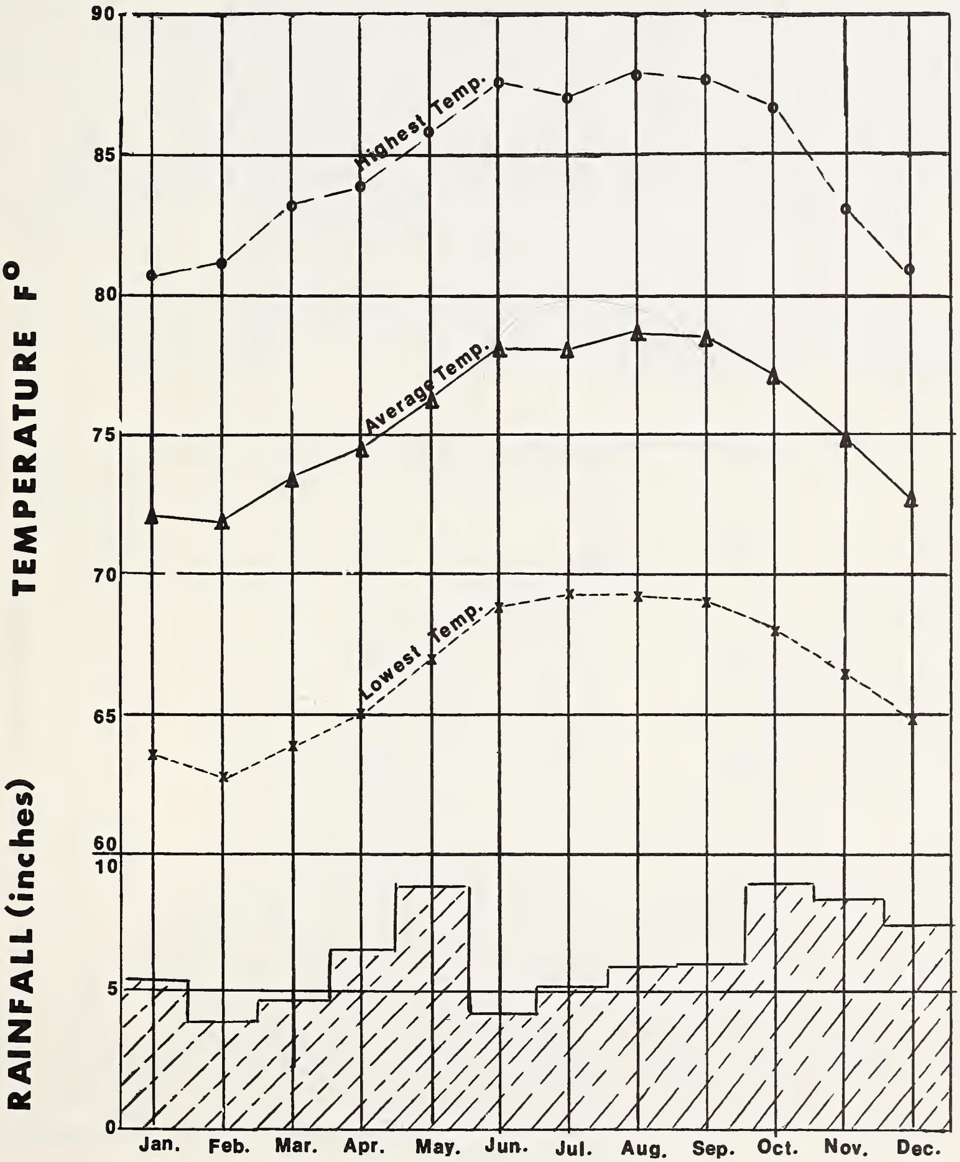

Fig. 1. Monthly rainfall and temperature under conditions typical of the humid region at Corozal, during the decade of 1962-1972.

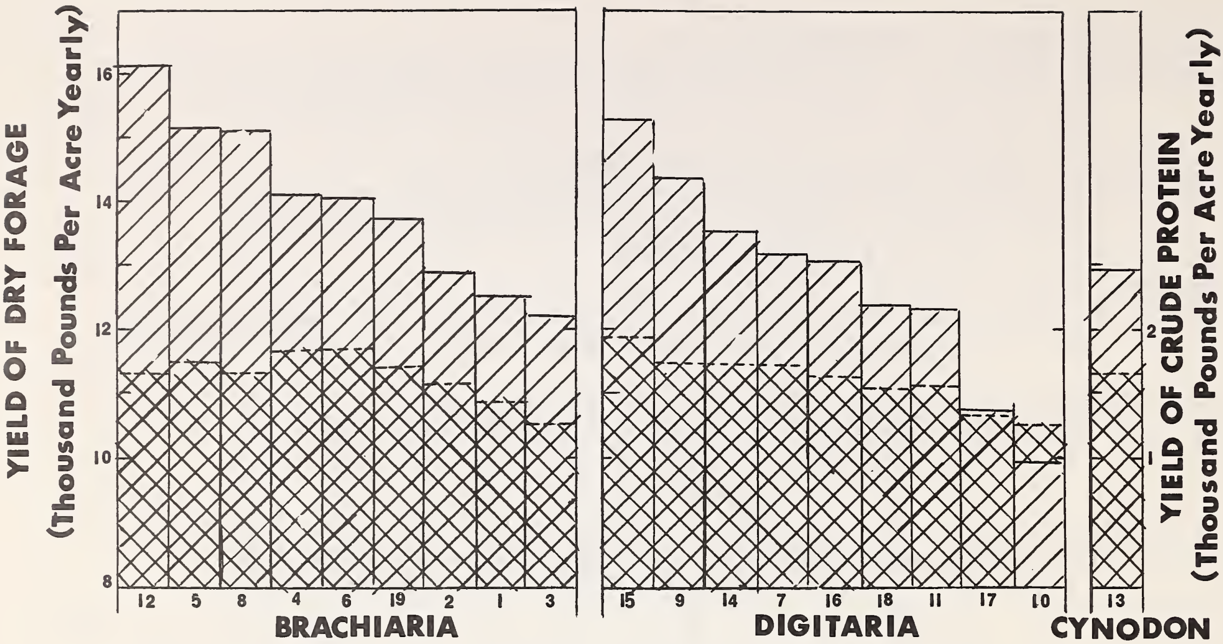

Fig. 2. Dry forage and crude protein yields of 19 grasses cut every 30 days over a 2-year period at Corozal.

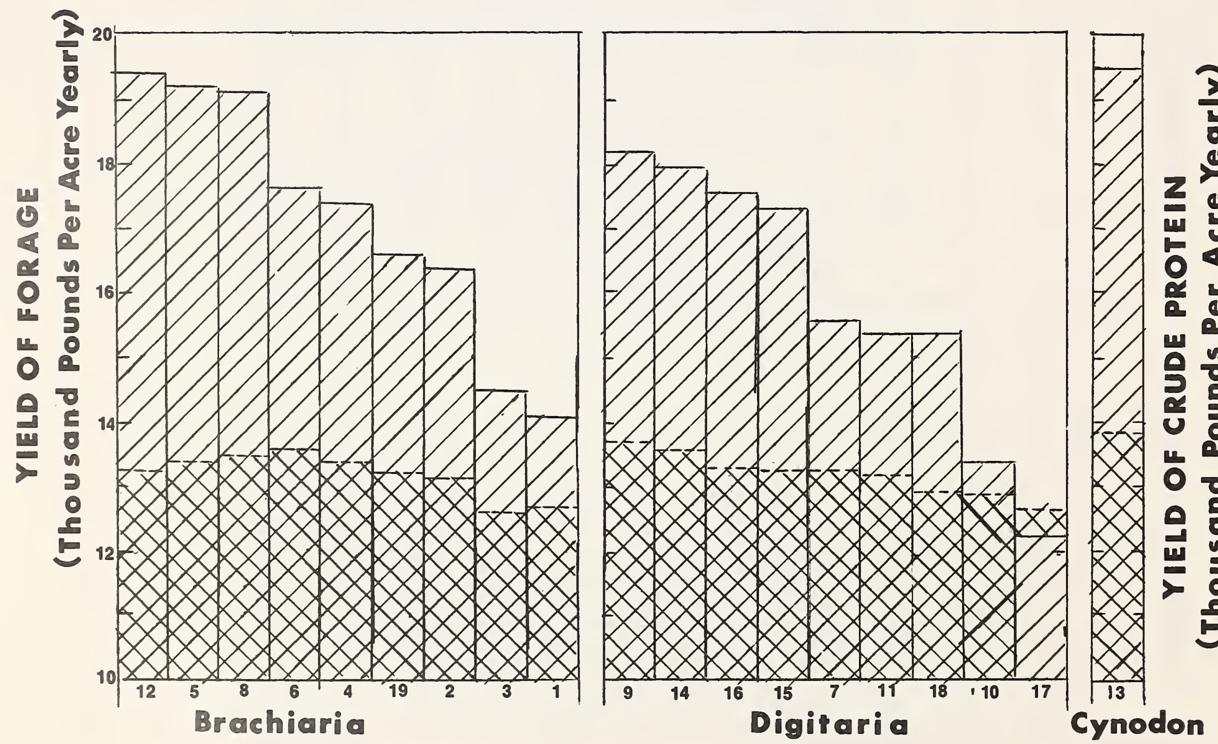

Fig. 3. Dry forage and crude protein yields of 19 grasses cut every 45 days over a 2-year period at Corozal.

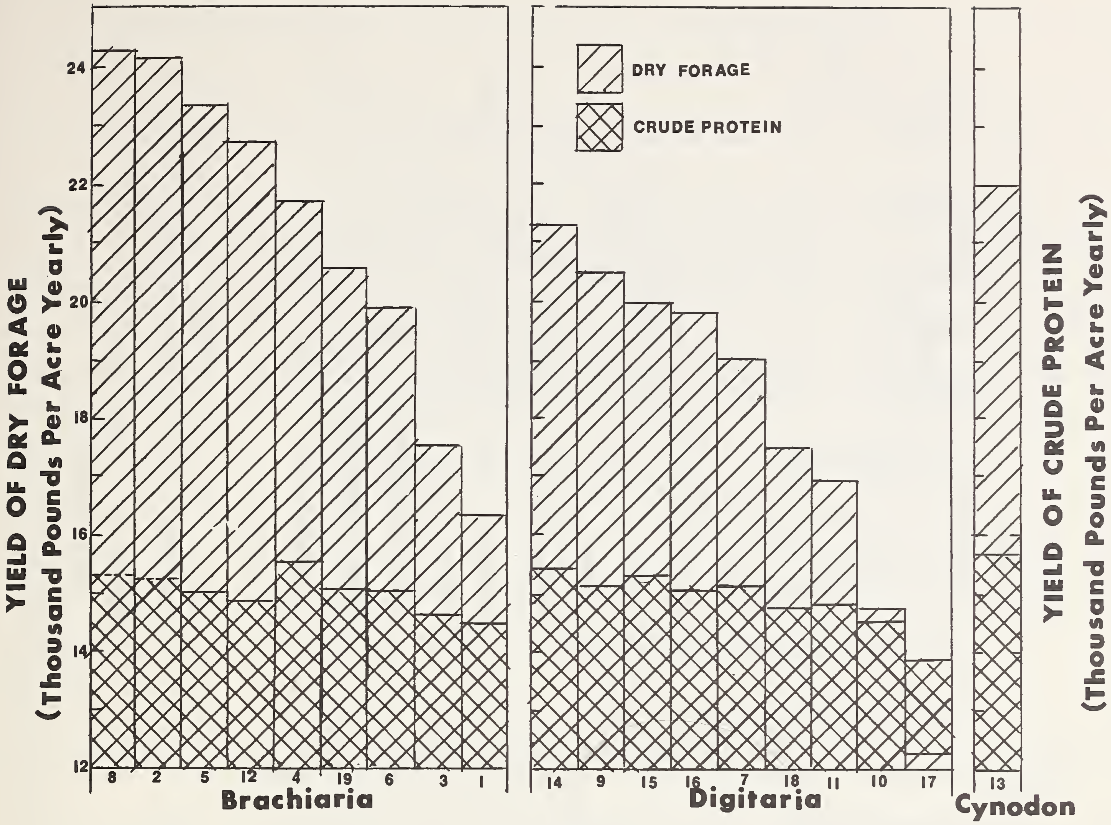

Fig. 4. Dry forage and crude protein yields of 19 grasses cut every 60 days over a 2-year period at Corozal.

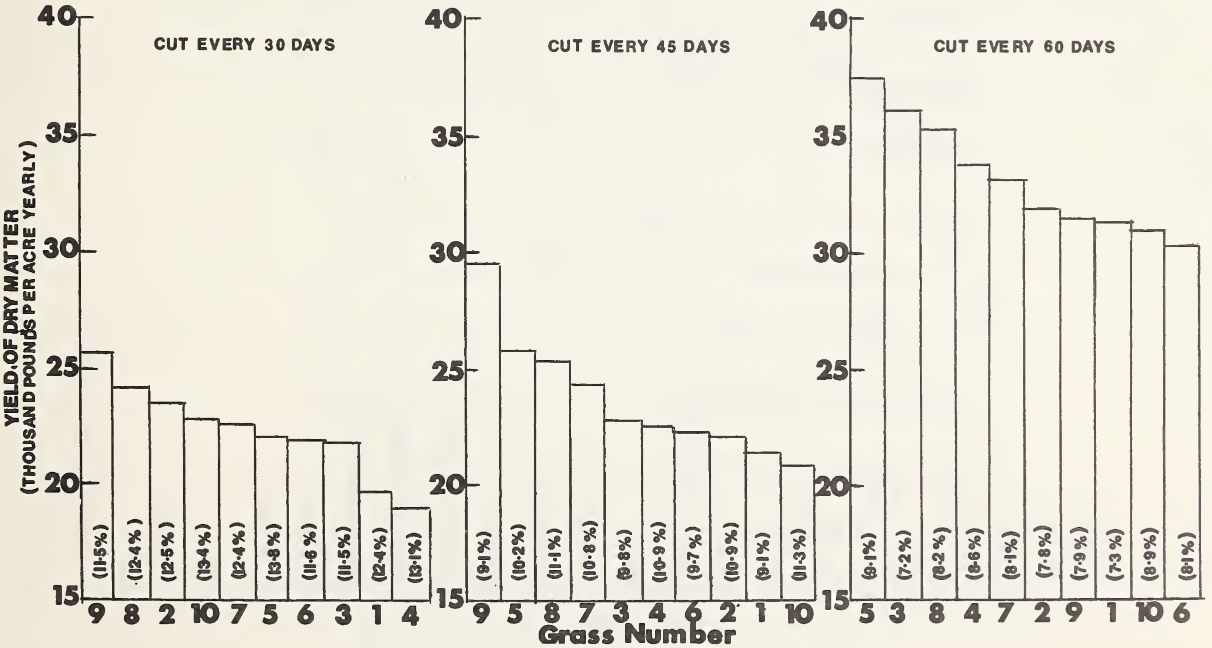

Fig. 5. The effect of frequency of cutting on yield and protein content of ten grasses over the period of one year. (Number in parentheses show percentage protein content of forage on a dry-matter basis).

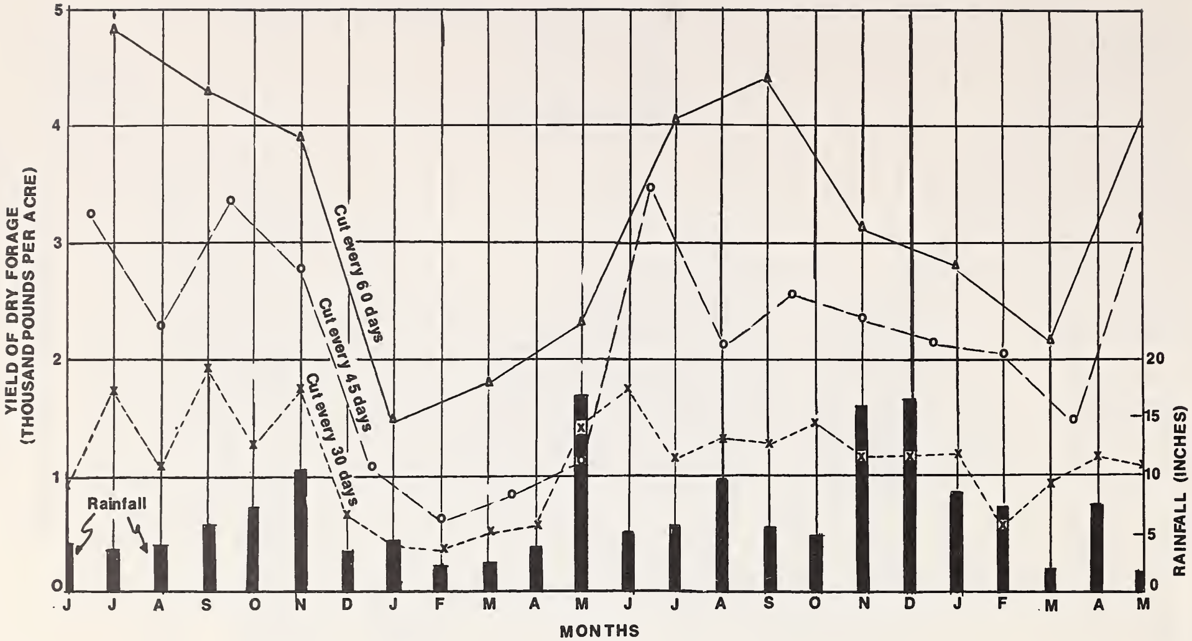

Fig. 6. Seasonal yields of dry forage per acre produced by 19 grasses cut every 30, 45, and 60-days over a 2-year period at Corozal.

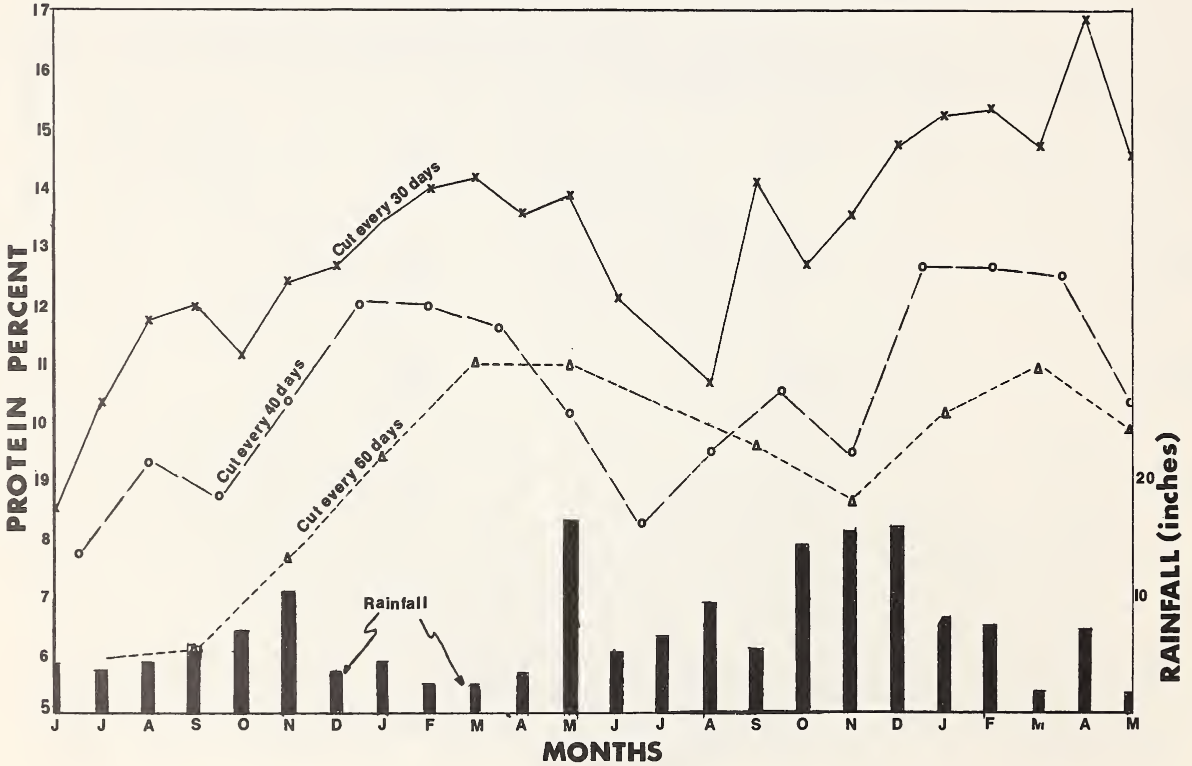

Fig. 7. Seasonal crude protein content per acre of 19 grasses cut every 30, 45, and 60-days over 2-year period at Corozal.

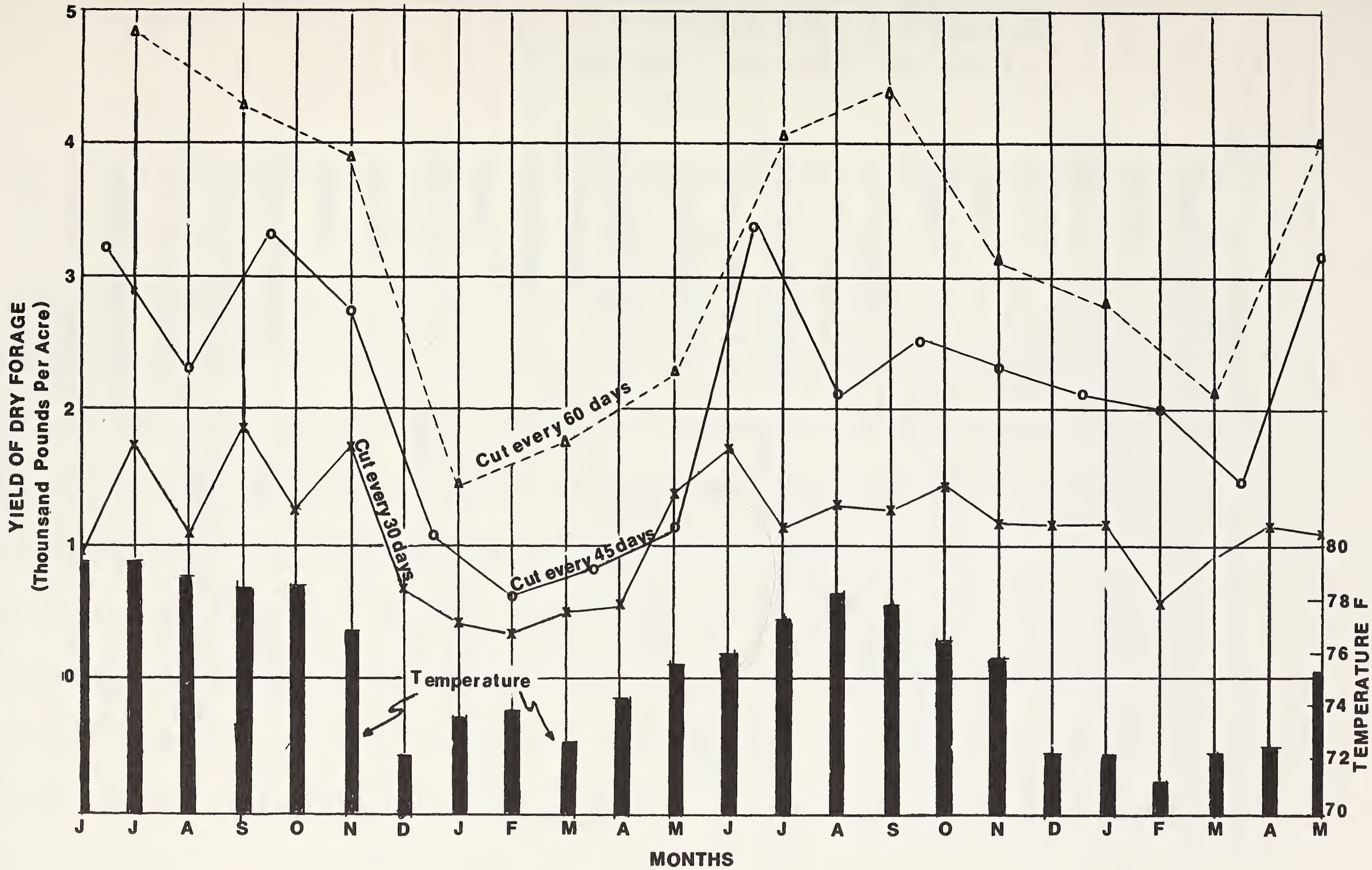

Fig. 8. Seasonal yields of dry forage per acre produced by 19 grasses cut every 30, 45, and 60 days as influenced by temperature over a 2-year period at Corozal.

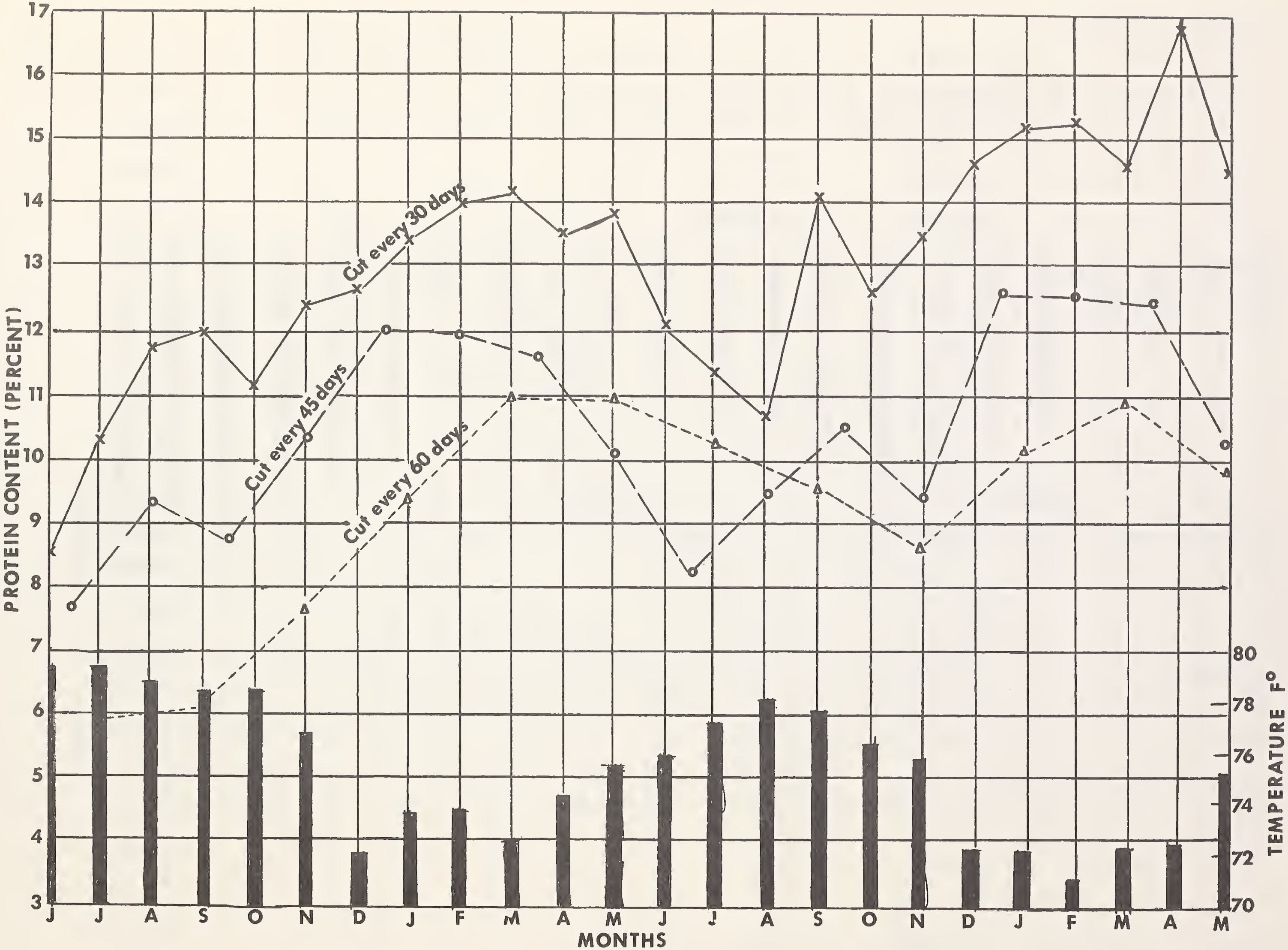

Fig. 9. Percent of crude protein of 19 grasses when cut every 30, 45, and 60 days as influenced by temperature over a 2-year period at Corozal.

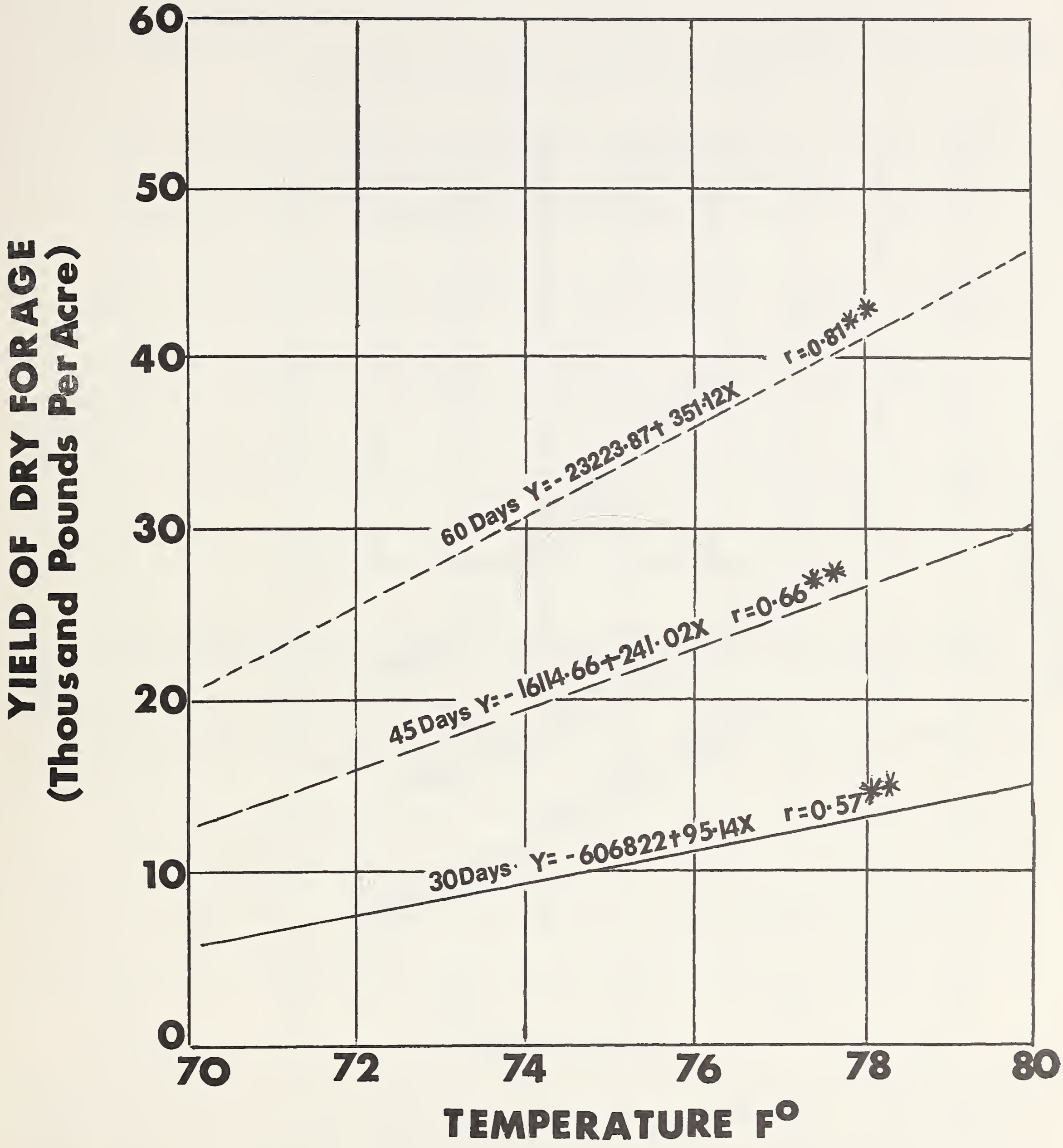

Fig. 10. Relationship between yield of dry forage per acre produced by 19 grasses cut every 30, 45, and 60 days over a 2-year period at Corozal and temperature.

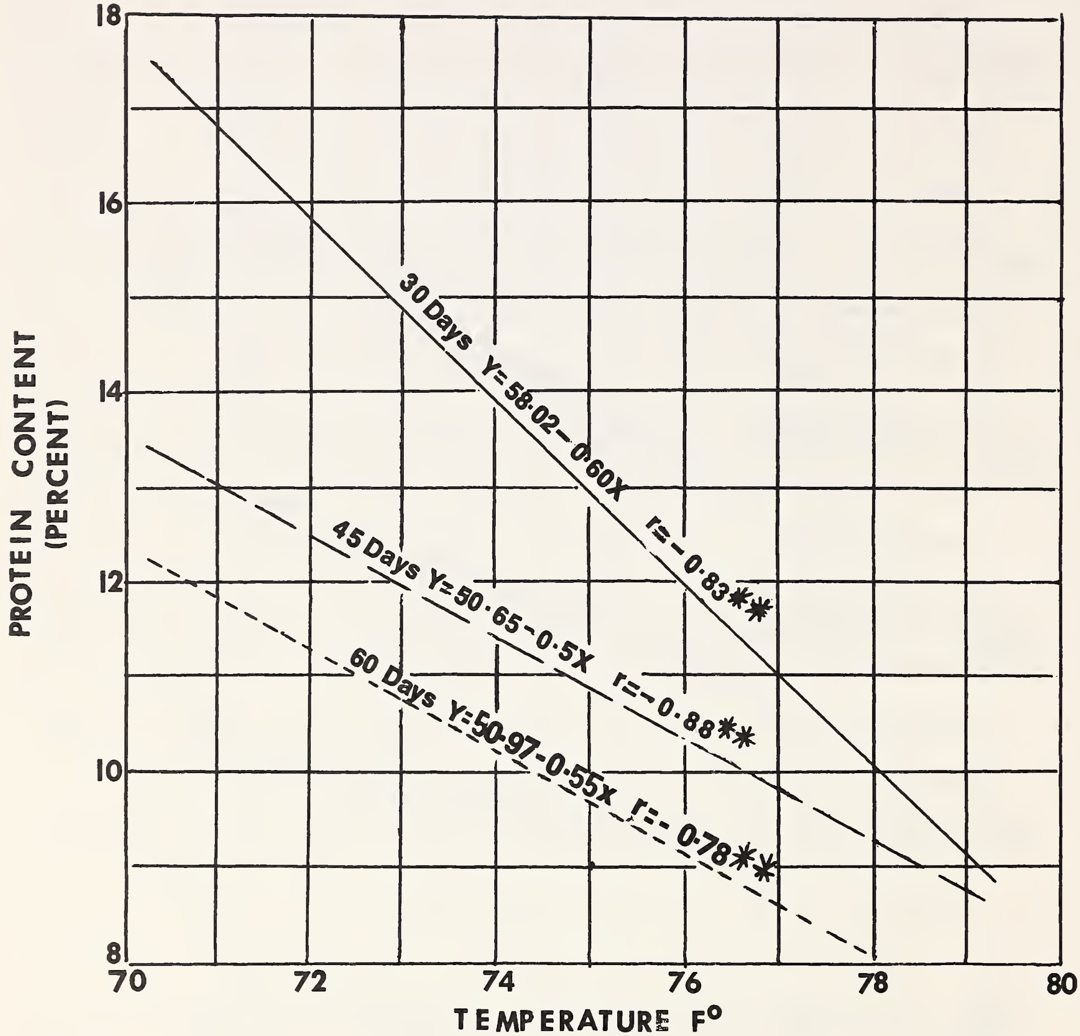

Fig. 11. Relationship between crude protein content of 19 forage grasses cut every 30, 45, and 60 days over a 2-year period and temperature.

AN INTENSIVE GRAZING 12-MONTH FORAGE SYSTEM FOR BEEF CATTLE WITH BERMUDAGRASS, WEEPING LOVEGRASS, AND SODSEEDED SMALL GRAINS

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The titled grasses and grains are commonly grown as forage in southern and central Oklahoma and other areas. However, little of this use is in a well integrated, intensive system by producers. The single most important complex objective, of this particular Noble Foundation Pasture Demonstration Farm grazing unit at Ardmore, Oklahoma, is to demonstrate the numerous integrated soil-forage-livestock, management facets and to illustrate the net profit possible on typical, eroded upland, worn-out cotton soil of the immediate region. The summarized report prohibits a detailed description of management so only typical management situations are briefly reported.

Soils and Climate. In their virgin state, the soils near Ardmore were basically loamy prairies series (See soil series map). Past farming practices have left 37% of the area void of topsoil, with the remainder moderately to severely eroded. Resultant soil moisture relationships and inherent nitrogen and phosphorus nutrient levels are very poor.

Precipitation is most prevalent during spring (April-June) and fall (September-October) in this 32-inch rainfall area. Severe regular summer droughts and occasional winter dryness have resulted in an average of 28 inches of precipitation for the last three years. Frost-free days range from late March or early April to early or mid-November.

Forage Program. The 72-Acre grazing unit is composed of 40 acres of Midland bermudagrass, 39.2 acres of Midland bermudagrass-weeping lovegrass mixture, and a 3.2-acre holding trap. The fencing plan, pasture division, and watering facilities are illustrated on the

following field map. One six-foot steel tank supplies water to four pastures while another steel tank supplies water to the other three pastures. A split pond in 10C and 10H supplies water to five pastures in case of well failure.

The bermudagrass-weeping lovegrass mixtures are the results of poor bermudagrass performance and the subsequence search to make the area more productive. The original bermudagrass area planted in 1964 was disked heavily to prepare a weeping lovegrass seedbed in 1970. Recommended planting of weeping lovegrass with starter fertilizer was accomplished, and good results have been obtained from the mixture. Grazing yields have been increased 50 to 100 grazing days per acre where good weeping lovegrass is established. Replicated plot clipping under uniform conditions is represented in Figure 1. Other research pointed out that moldboard plowing as opposed to disking for initial seedbed was three times better for producing maximum early weeping lovegrass establishment and yields. The bermudagrass-weeping lovegrass pastures are managed basically as weeping lovegrass pastures.

The major advantages of weeping lovegrass when compared to bermudagrass are its early spring greening, later fall green retainment, and its ability to remain standing for field-cured winter roughage. We would still prefer pure stands of each grass, in most cases, to warrant more management control. This mixture, however, has allowed an improvement over pure bermudagrass. Banded starter fertilizer response has proven important in establishing weeping lovegrass (Figure 2). In this case, all areas also received a nitrogen topdressing the first year after the emergence of weeping lovegrass.

Sodseeding small grains into bermudagrass or bermudagrass-weeping lovegrass sod is done each fall for purposes of supplying stocker calf grazing, nursing calf creep feed, and cow limit grazing for protein. As the planting season approaches, cows graze bermudagrass pasture down to two to four inches high before sodseeding with a John Deere narrow point hoe drill. Planting is done during September 15 to 20 and continues to mid-November, when the pastures are grazed down and good soil moisture prevails in the upper 10 to 12 inches. Only rye and a small amount of ryegrass have been used recently in this procedure; wheat and oats have not regularly performed well

in previous cases. This system is very refined as to methods and management; time and space does not allow the discussion of this refinement.

Fertilizer. Soils test low to very low in phosphorus; therefore, nitrogen and phosphorus are the major nutrients applied. Liming has not been done. Due to irregular rainfall patterns during the summer, varying rates have been used. In general, the rates and periods of application are as follows. Spring applications are always made, while summer and fall applications are done more in accordance with the rainfall received and production needed. (Table 1).

Livestock. The cows are black Angus and are bred to a Charolais bull to calve during the fall. Stocker cattle are locally purchased #1 Okies or better types. Stocker cattle are chosen on the basis of winter pasture acreage and performance. Generally, the stocking rate is one to one and one-half stockers per acre of winter pasture, plus allowances for creep grazing by nursing calves. Excess is used for cow limit grazing.

The cows are vaccinated for leptospirosis annually and sprayed two or three times for lice and flies. Stockers are medicated thoroughly at arrival and implanted with stilbestrol. Recently, nursing calves have also received implants, but new restrictions will alter this use.

Creep gates are placed throughout the system to allow nursing calves free access to all forages after the oldest calves are approximately two months old. This has been quite beneficial in other years and systems. Further analysis of the gains of creep-graze calves as compared to non-creep-graze calves is being done.

Economics. The final success or failure of any pasture system is in its profits or losses. The economical results of the first two years are presented in Tables 1 through 5.

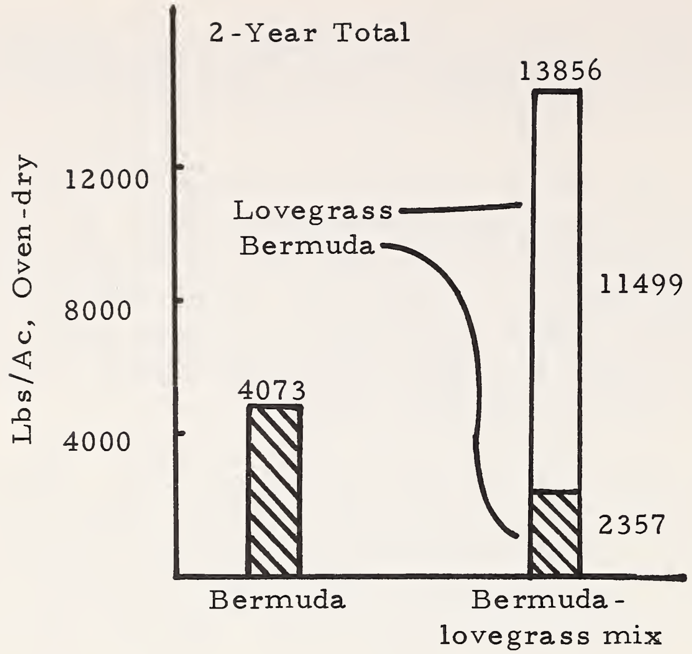


Figure 1. Comparative Yield of Midland Bermuda Alone and a Bermuda-Weeping Lovegrass Mixture.

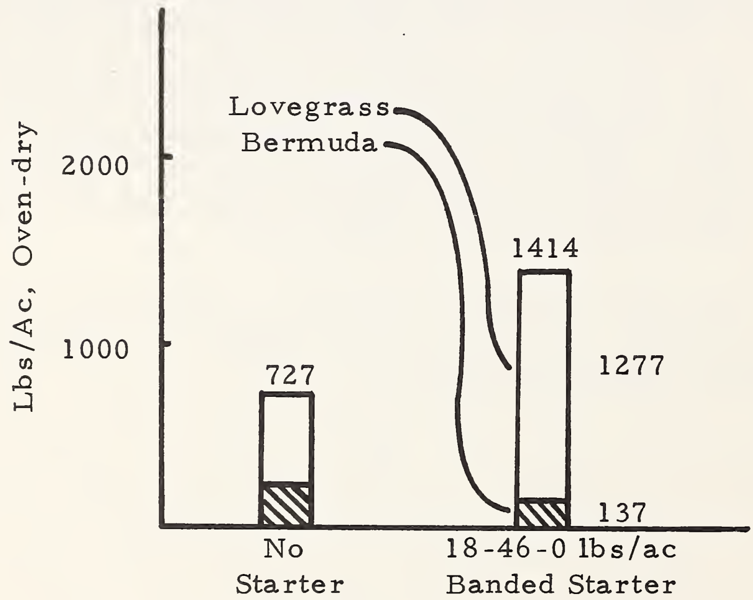


Figure 2. First Season Response from Starter Fertilizer when Planting Weeping Lovegrass into Midland Bermuda.

Table 1. Fertilizer Applied in the Noble Foundation Pasture Demonstration Farm Intensive Grazing Unit.

	Rate (Lbs. /Acre)		
Pasture	Nitrogen	Phosphorus	Period of Application
Bermudagrass	75-100	30-40	First topdressing - late April to May.
	70-80	---	Second topdressing - late summer (by September). If the bermudagrass is sodseeded, the phosphorus is applied with the sod-seeded crop.
Bermudagrass-lovegrass mixture	75-100	30-40	First topdressing - March.
	70-80	---	Second topdressing - May.
	70-80	---	Third topdressing - August to September.
Sodseeded Small Grains	20	50	Banded starter.
	100	---	First topdressing - November to January.
	100	---	Second topdressing.

Table 2. Calculated Returns Summary from Differing Land Payment Expenses and Cow Mortgage Payments. Intensive Grazing Unit. Noble Foundation Pasture Demonstration Farm. Ardmore, Oklahoma.

	Land Purchase Cost per Acre			
	$100	$200	$300	$400
Year One (1970-71) Income 1/	$3,975.14	$3,975.14	$3,975.14	$3,975.14
Less land payment 2/	679.68	1,359.36	2,039.04	2,718.72
Net after land payment	3,295.46	2,615.78	1,936.10	1,256.42
Less first cow mortgage payment 3/	2,524.50	2,524.50	2,524.50	2,524.50
Net after cow payment	770.96	91.28	-588.40	-1,268.08
NET per Acre	$ 10.71	$ 1.27	$ -8.17	$ -17.61
	(4.56%)	(0.52%)	(-3.22%)	(-6.70%)
Year Two (1971-72) Income	$4,027.78	$4,027.28	$4,027.28	$4,027.28
Less land payment	679.68	1,359.36	2,039.04	2,718.72
Net after land payment	3,348.10	2,667.92	1,988.24	1,308.56
Less second cow mortgage payment	2,371.50	2,371.50	2,371.50	2,371.50
Net after cow payment	976.60	296.42	-383.26	-1,062.94
NET per Acre 4/	$ 13.56	$ 4.12	$ -5.32	$ -14.76
	(4.95%)	(1.45%)	(-1.82%)	(-4.88%)

1/ From Tables 1A and 1B.
2/ From Table 3.
3/ From Table 4.
4/ Numbers in parentheses represent the percentage of return on the total annual expenses for that year at that payment scale, using the expenses from Tables 1A and 1B plus expenses from Table 4 divided into net after cow payment.

Table 3. Equal Land Payment Schedule for a Hypothetical 20-Year Loan at 7% Interest. Intensive Grazing Unit. Noble Foundation Pasture Demonstration Farm. Ardmore, Oklahoma.

Initial Land Purchase Value	Total Cost for 72-Acre	Annual Payment for 20 Years
$100/Acre	$ 7,200.00	$ 679.68
$200/Acre	14,400.00	1,359.36
$300/Acre	21,600.00	2,039.04
$400/Acre	28,800.00	2,718.72

Table 4. Annual Cow-Bull Payments for a Hypothetical 100% Initial Loan with a Four-Year Pay-out at 8% Interest. Intensive Grazing Unit. Noble Foundation Pasture Demonstration Farm. Ardmore, Oklahoma.

Year	Outstanding	Principle Payment	Interest	Total Annual Payment
1	$7,650.00	$1,912.50	$612.00	$2,524.50
2	5,737.50	1,912.50	459.00	2,371.50
3	2,825.00	1,912.50	306.00	2,218.50
4	1,912.50	1,912.50	153.00	2,065.50

Table 5. Returns to Management. Intensive Grazing Unit. Noble Foundation Pasture Demonstration Farm. Ardmore, Oklahoma.

Expense or Return	1970-71	1971-72
Production Expenses[1/]	$13,470.91	$16,412.15
Total Income	17,667.74	20,733.29
Returns to Land, Labor, Capital, & Management	$ 4,196.83	$ 4,321.14
Allocation of Returns:		
Land Charge[2/]	$ 864.00	$ 864.00
Labor Charge[3/]	584.00	584.00
Capital Charge[4/]	1,150.84	1,268.49
TOTAL	$ 2,598.84	$ 2,716.49
Return to Management[5/]	$ 1,597.99 (5.55%)	$ 1,604.65 (5.30%)

[1/] Total expenses from Tables 1A and 1B minus interest on stockers.

[2/] Land charge is based on $200 per acre land at 6% interest. This interest rate reflects current insured savings and loan association rates.

[3/] Labor for livestock at $1.60 per hour. Labor income for pasture operations included in custom rates charged in production expenses.

[4/] Capital for cattle and production expenses on an annual basis at 8%.

[5/] Numbers in parentheses represent the percentage of return on the investment for that year. The total investment includes land ($200 per acre), cows, and production expenses on a yearly basis.

Table 1A. First Year (1970 Fall to 1971 Fall) Expenses and Income. Intensive Grazing Unit. Noble Foundation Pasture Demonstration Farm, Ardmore, Oklahoma.

Item	Cow-Calf Unit[1]			Stocker Unit[2]			Total Costs (72-Acre Basis)	
	/Acre	/Head	Total	/Acre	/Head	Total	/Acre	Total
EXPENSES	$	$	$	$	$	$	$	$
Livestock:								
Cows & Bull (37)[3]	-	-	-	-	-	-	-	-
Stockers (45)	-	-	-	190.96[2]	169.74	7,638.51	106.09	7,638.51
Stocker Interest (8%)	-	-	-	5.54	4.92	221.69	3.08	221.69
Pastures:	25.38	70.76	2,547.26	35.32	31.39	1,412.64	55.00	3,959.90
Feeds, Salt, & Minerals:								
Cow supplement	7.92	15.83	569.95	-	-	-	7.92	569.95
Cow hay	.09	.18	6.30	-	-	-	.09	6.30
Calf creep feed	3.15	6.30	226.89	-	-	-	3.15	226.89
Stocker supplement	-	-	-	3.90	3.47	156.17	2.17	156.17
Stocker hay	-	-	-	.62	.55	24.80	.34	24.80
Pasture rent	-	-	-	1.58	1.40	63.00	.88	63.00
Salt & Mineral	.94	1.89	68.00	.23	.20	9.00	1.07	77.00
Ear Tags:								
Cows (36)	.18	.36	12.95	-	-	-	.18	12.95
Calves (34)	.09	.19	6.80	-	-	-	.09	6.80
Stockers (45)	-	-	-	.13	.11	5.00	.07	5.00
Vet, Medicine, & Pest Control: (Includes Implants)	1.28	2.56	92.28	2.17	1.93	86.85	2.49	179.13
Hauling & Commission: (Included in Buy-Sell Transaction)								
Electricity:	.33	.67	24.00	-	-	-	.33	24.00
Fences & Equipment:	4.55	9.10	327.61	-	-	-	4.55	327.61
Taxes:								
Cattle (116)	1.70	3.32	122.70	.68	.60	27.00	2.08	149.70
Land (72-Acre)	.60	1.17	43.20	-	-	-	.60	43.20
TOTAL EXPENSES	56.22	112.44	4,047.94	241.12	214.32	9,644.66	190.18	13,692.60
INCOME								
Livestock:								
Cull Cows (8 @ $169.70)	18.85	37.71	1,357.48	-	-	-	18.85	1,357.48
Calves (34 @ $168.14)	79.40	158.80	5,716.95	-	-	-	79.40	5,716.95
Stockers (45)	-	-	-	264.83	235.41	10,593.31	147.13	10,593.31
TOTAL INCOME	98.26	196.51	7,074.43	264.83	235.41	10,593.31	245.39	17,667.74
NET to LAND, LABOR, CAPITAL, & MANAGEMENT[4]	$42.03	$84.07	$3,026.49	$23.69	$21.06	$947.65	$55.21	$3,975.14
% Return on Expenses	-	-	74.8%	-	-	9.8%	-	29.03%
% Return on Annual Basis	-	-	74.8%	-	-	19.6%	-	29.03%

[1] 36 cow basis.
[2] Stockers figured on basis of 40 acres of winter pasture.
[3] Original cows and bull bought first year on 100% loan basis; repayment of loan in Table 2.
[4] Interest has been paid on stockers and labor has been paid on pasture costs.

Table 1B. Second Year (1971 Fall to 1972 Fall) Expenses and Income. Intensive Grazing Unit. Noble Foundation Pasture Demonstration Farm, Ardmore, Oklahoma.

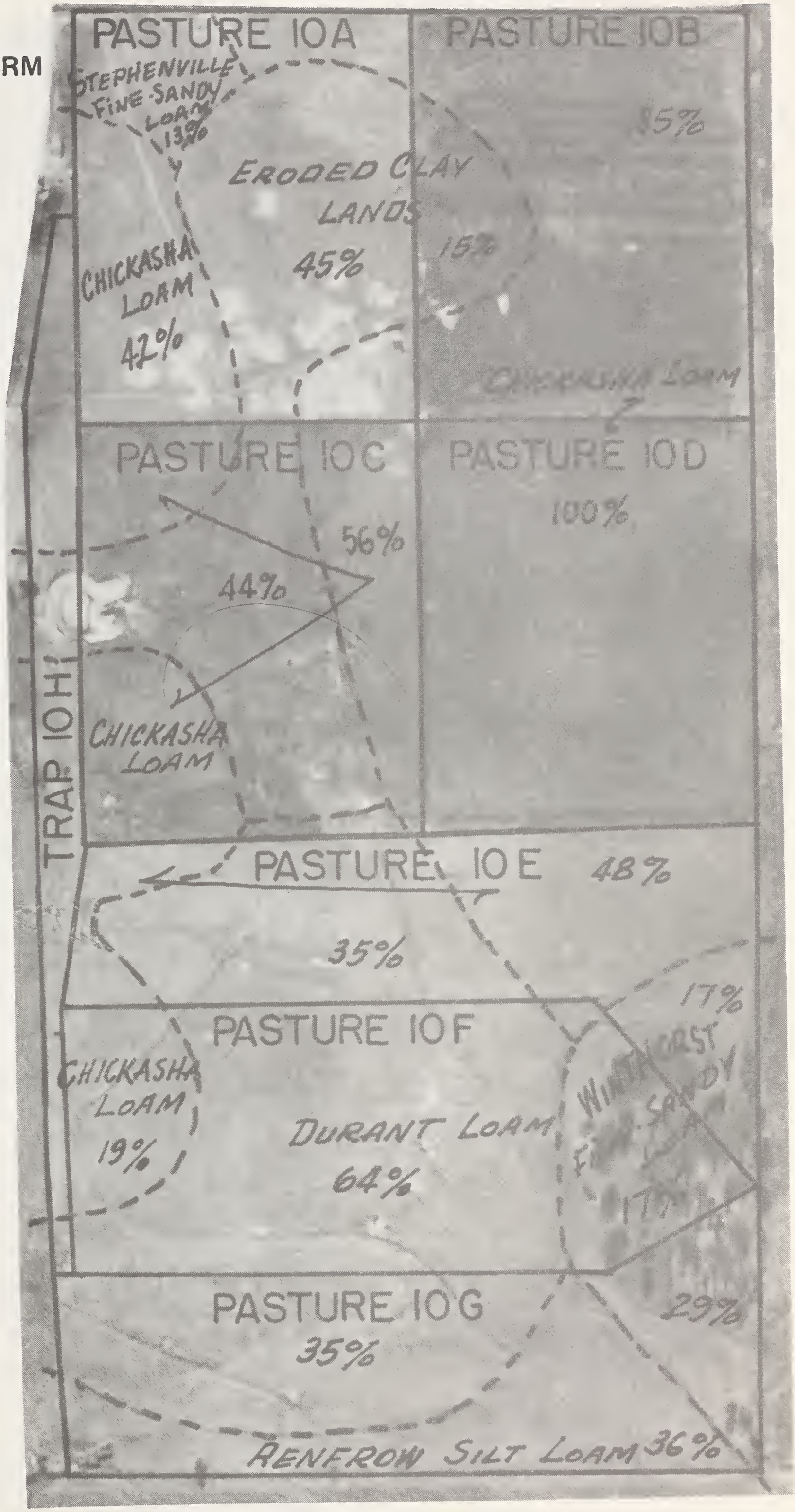
Item	Cows[2]			Stockers[2]			Total Cost (72-Acre Basis)	
	/Acre	/Head	Total	/Acre	/Head	Total	/Acre	Total
EXPENSES	$	$	$	$	$	$	$	$
Livestock:								
Replacement Cows (17)	65.28	130.56	4,700.00	-	-	-	65.28	4,700.00
Stockers (46)	-	-	-	249.25	162.56	7,477.63	103.86	7,477.63
Stocker Interest (8%)	-	-	-	9.79	6.38	293.36	4.07	293.36
Pastures:	17.67	35.35	1,272.45	50.65	33.03	1,519.50	38.78	2,791.95
Feeds, Salt, & Minerals:								
Cow concentrate	6.35	12.70	457.12	-	-	-	6.35	457.12
Cow hay @ 70¢/bale	.04	.08	2.80	-	-	-	.04	2.80
Calf creep feed	1.90	3.80	136.89	-	-	-	1.90	136.89
Stocker concentrate	-	-	-	9.37	6.10	281.00	3.90	281.00
Stocker hay @ 70¢/bale	-	-	-	.09	.06	2.80	.04	2.80
Salt & Minerals	.94	1.89	68.00	1.42	.92	42.50	1.53	110.50
Ear Tags:								
Cows	.08	.16	5.95	-	-	-	.08	5.95
Calves	.09	.18	7.00	-	-	-	.10	7.00
Stockers	-	-	-	.16	.10	4.80	.07	4.80
Vet, Medicine, & Pest Control: (Includes implants)	1.19	2.40	86.26	3.73	2.43	111.80	2.75	198.06
Hauling & Commission: (part in other expenses)	-	-	-	.45	.29	13.55	.19	13.55
Electricity:	.33	.67	24.00	-	-	-	.33	24.00
Fences & Equipment: (salt feeders)	.04	.07	2.60	.04	.06	2.60	.07	5.20
Taxes:								
Cattle (116)	1.70	3.40	122.70	.90	.60	27.00	2.08	149.70
Land (72-acres)	.60	1.20	43.20	-	-	-	.60	43.20
TOTAL EXPENSES	96.24	192.47	6,928.97	325.88	212.53	9,776.54	232.02	16,705.51
INCOME								
Livestock:								
Cull Cows (14 @ $210.26)	79.56	82.78	2,943.64	-	-	-		2,943.63
Calves (35 @ $184.81)	88.38	176.76	6,363.33	-	-	-		6,363.33
Stockers (45)	-	-	-	360.13	234.87	10,804.03		10,804.03
Hay (889 bales @ 70¢)	8.64	17.29	622.30	-	-	-		622.30
TOTAL INCOME	137.91	275.82	9,929.27	360.13	234.87	10,804.03	287.96	20,733.29
NET to LAND, LABOR, CAPITAL & MANAGEMENT[3]	41.67	83.36	3,000.30	34.25	22.34	1,027.49	55.94	4,027.78
% Return on Expenses			43.3%			10.5%		24.1%
% Return on Annual Basis			43.3%			21.0%		24.1%

[1]36 cow basis.
[2]Stockers figured on basis of 30 acres of winter pasture.
[3]Interest has been paid on stockers and labor has been paid on pasture costs.

NOBLE FOUNDATION
PASTURE DEMONSTRATION FARM
Intensive Stocking Unit
Ardmore, Oklahoma

SOIL SERIES PERCENTAGE OF
TOTAL ACREAGE - 72 ACRES

Series	% of Area
Chickasha Loam	
1-3% slope	48.2
Durant Loam - Severely Eroded	
1-5% slope	19.5
Eroded Clay Lands	17.4
Winthorst Fine-Sandy Loam	
3-5% slope	7.6
Renfrow Silt Loam	5.5
Stephenville Fine-Sandy Loam	1.8
Total	100.0%



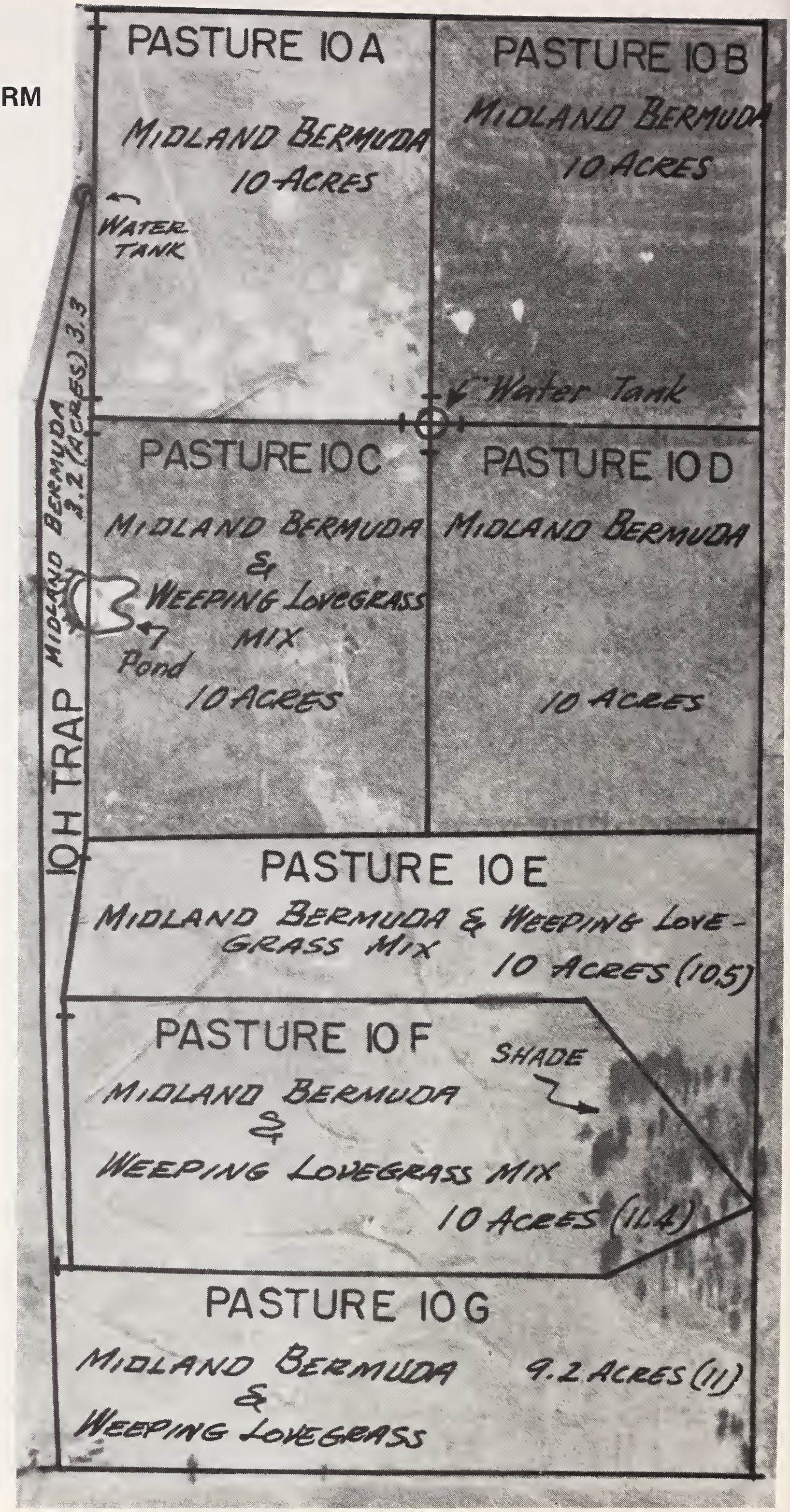
NOBLE FOUNDATION

PASTURE DEMONSTRATION FARM

Intensive Stocking Unit

Ardmore, Oklahoma

SCALE: 8″= ½ mile
gates
No. before()= grass acres
No. in ()=total fenced acres



YEAR-ROUND FORAGE SYSTEMS FOR BEEF CATTLE IN ARKANSAS

By A. E. Spooner and Maurice L. Ray 1/

The beef cattle business in Arkansas is predominately a cow-calf program designed to produce feeder calves. Most of these calves leave the state at weaning and are fattened in western Oklahoma, Texas and Kansas on winter wheat. They are fed in the feed lots of these areas to slaughter weight and grade. The best estimates available to us indicate that about 80 percent of our calves follow the above route with the other 20 percent being raised in the state.

Our research over the past 15 to 18 years has been designed primarily to evaluate year-round pasturing systems for the cow-calf program. We are utilizing two base grasses in this program, bermudagrass and tall fescue. The percent of each grass of the total pasture allotted depends on the location within the state. We recommend that two-thirds of the acreage in northern Arkansas and one-half of the acreage in southern Arkansas be seeded to tall fescue. This difference is based on the length of the growing season for each of the grasses for each area.

We are deferring or stockpiling tall fescue for grazing during late December, January, February, and early March. We defer one-half of the allotted acreage of tall fescue and utilize the other one-half for grazing in the late fall, early winter, and late spring. The bermudagrass is for summer grazing. Therefore, nearly the only time that we must feed hay, using this system, is during periods of snow cover, or during an extended drought period, primarily in the summer. We harvest enough hay to supply each cow with 1 ton each year if needed. We have had to feed hay at our Pine Tree Project for 8, 6, and 22 days for the years of 1969, 1970, and 1971, respectively.

We have recently started a year-round pasture program for raising and finishing calves and yearlings at our Beef Substation at Newport, Ark. We are using a center pivotal irrigation system to irrigate 165 acres on a year-round basis as needed. We are using bermudagrass interseeded with tall fescue, bromegrass, orchardgrass, or annual ryegrass, and overseeded with 'Regal' white clover as, our species mixtures. Calves are put on these pastures at weaning and fattened until they weigh about 750 to 800 pounds. They are given a full feed of grain or pasture for about 60 to 75 days and are then sent to slaughter weighing about 1000 to 1050 pounds, grading high good to low choice. We feel that this type of a program will be used more in the near future in Arkansas.

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USING FORAGES IN COW-CALF PRODUCTION, GROWING AND FATTENING CATTLE

By E. R. Beaty 1/

Traditionally, the Southeast has been a producer and exporter of feeder calves. Thus far, markets have been readily available for the calves produced, and farmers in general have been satisfied with prices received. The beef industry in the South has reached a volume at which continued reliance on a single marketing system poses serious risk. As an example, should the market for feed grains expand enough to make cattle feeding unprofitable, tested alternate systems should be available to prevent market collapse. In addition, it is probable that the time has come for the South to develop a total cattle program as a matter of its own opportunity and heritage.

In the South, high-quality forages such as winter grazing and arrowleaf clover are available during parts of the year. We still have problems with high-quality forage in the summer, but by combining cool and warm-season perennials such as tall fescue and 'Coastal' or common bermudagrass we can economically produce forage for 10 to 12 months.

We need data on base forage production and animal gain to build core cattle production programs. The core programs should include the various stages in the growth of cattle from birth until marketed as calves, feeder steers, or as fat cattle, and should consider the forages present for grazing during the different size stages. Since feed grains are limited in the South, the core model should rely on grazing major forages while in season. Cattle being produced on such a system may be marketed at weights up to 1,200 pounds, and the time required to reach a given weight can be adjusted by substituting harvested feed.

Table 1 includes a number of forage and livestock production possibilities. A calf dropped in February may be grazed until October on tall fescue, bermudagrass, or bahiagrass. Average weaning weights are likely to be 400 to 450 pounds. The weaned calves can be sold or wintered on hay, tall fescue, and winter grazing, and by the following May should weigh 600 to 700 pounds. During the summer the stocker cattle can be grazed on tall fescue or bermudagrass. They should weigh 700 to 850 pounds by October and be ready to finish at 1,050 to 1,150 pounds on winter grazing of rye, ryegrass, and arrowleaf clover.

Another possibility is to winter the weaned calves on winter grazing, then graze them on millets or sudans the following summer. By the end of the winter grazing period, the cattle should average 750 pounds in weight, and by September or October a weight of 950 to 1,050 pounds have been reached.

Such a system uses time as a variable in production, and rate of cattle growth can be increased by substituting high-quality forages such as clover, and winter and summer temporaries for tall fescue or bermudagrass. Such

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substitutions may well increase the cost of cattle production. Depending upon availability and relative cost, limited feeding of grain with tall fescue and bermudagrass will get cattle to a heavier weight or to market earlier but will probably increase cost of production.

TABLE 1.--Growth Stages, Available Forage, and Attainable Weights for Calves Grown in Georgia.

Stage	Period	Available forage	Weight at end of period (pounds)
Cow-calf	February - October	Bermudagrass, fescue	400 to 450
Stocker	October - May	Winter temporary grazing, hay, tall fescue	600 to 700
Stocker	May - October	Bermudagrass, tall fescue, summer temporary grazing	700 to 850
Fat Steer	October - May	Winter grazing, arrowleaf clover, limited grain ration	1,050 to 1,150

POTENTIAL FOR HYBRID VARIETIES IN PERENNIAL FORAGE SPECIES

By Glenn W. Burton [1]

HETEROSIS

Heterosis, the increased vigor of the F_1 hybrid over its parents, is a very significant phenomenon. I believe it is as universal as dominance and will one day be demonstrated in all species. If this is true, once practical methods for its use have been developed and parents conferring substantial amounts of heterosis have been found, it may be used to increase the yield and efficiency of any forage species.

Heterosis has been demonstrated in many forage species. Tysdal, et al., (11)[2] described 10 alfalfa, *Medicago sativa* F_1s that yielded an average of 15 percent more than the checks. The best of these hybrids outyielded the check by 39 percent. Hayes and Schmid (9) produced nine F_1 hybrids between S_1 clones of bromegrass, *Bromus inermis*, that gave forage yields ranging from 126.5 to 220.9 percent of the checks. They also reported that 14 F_1 crosses in orchardgrass, *Dactylis glomerata*, gave an average yield of 132.9 percent of the check. Burton (2) reported marked heterosis, ranging from 25 to 100 percent, in F_1 hybrids of 'Pensacola' bahiagrass, *Paspalum notatum*; napiergrass, *Pennisetum purpureum*; pearl millet, *Pennisetum americanum*; and bermudagrass, *Cynodon dactylon*. Open-pollinated progenies of 10 plants of commercial sericea lespedeza, *Lespedeza cuneata* outyielded self-pollinated progenies by 25.2 percent and the commercial check by 11.6 percent, according to Donnelly (8). The best of his outcrosses yielded 27.8 percent more than the commercial check, demonstrating the existence of significant amounts of heterosis in this species.

With such potential, one may well ask why there are no commercial high-yielding hybrid varieties of seed-propagated forage species like bromegrass, alfalfa, orchardgrass, etc. A lack of practicable methods for commercial hybrid-seed production is probably the main answer. Mediocre parents capable of delivering much less than the maximum potential heterosis is also an important part of the answer. No perennial forage species, except possibly alfalfa, has been well enough screened for heterosis to indicate the potential.

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[1] Geneticist, Georgia Coastal Plain Experiment Station, Southern Region, Agriculture Research Service, U.S. Department of Agriculture, Tifton, GA.

[2] Underline numbers in parentheses refer to items in literature cited at the end of this paper.

Heterosis observed in space-plant nurseries frequently becomes insignificant in plots seeded at standard seeding rates. Seeding Pensacola bahiagrass at a rate of 10 pounds of seed per acre puts some 60 seeds per square foot. If all seeds germinate, interplant competition soon becomes severe, and many plants (presumably the less vigorous ones) usually die in the first year. This leads to the question, "Are there enough high-yielding plants in the open-pollinated check variety to leave a surviving population comparable to the hybrid?". The answer to this question could help to explain the failure of good space-plant hybrids when seeded in test plots. If this is the case, seeding test plots at rates greater than on-farm rates to insure a quick stand could place the hybrid at a disadvantage.

METHODS FOR COMMERCIAL F_1 HYBRID PRODUCTION

Methods of reproduction and commercial propagation determine the manner in which heterosis may be used in forage breeding. If practical methods can be found for vegetatively propagating the improved variety on the farm, making use of heterosis is simple. It then depends on the combination of two gametes that give the maximum heterosis and bring together other desired characters. The bearers of the gametes must be found, and suitable hybridization techniques must be discovered. Complete apomixis, sterility, or incompatibility may present stubborn obstacles. Finally, screening techniques must be designed that will permit the isolation of the superior plant.

Vegetative Propagation. Most of the outstanding hybrid varieties of perennial forages are vegetatively propagated. Vegetative propagation offers many advantages. The breeder need develop only one superior plant. Vegetative propagation eliminates progeny testing, maintains desirable traits, permits wide crosses that are often sterile, and facilitates identification and control. Thirty years ago, most forage specialists would have quickly ruled out vegetative propagation as a practical method for establishing forages. Today stoloniferous grasses like bermudagrass (3) can be successfully propagated vegetatively more cheaply than with seed. We need more research on developing methods of vegetatively propagating superior bunchgrasses. An economical and dependable method of vegetatively planting bunchgrasses would enable forage breeders to quickly place high-yielding hybrids of all forages on the farm.

Apomixis. Apomixis, vegetative reproduction through the seed, offers a means of fixing a desired genotype and maintaining its heterosis. To date, this phenomenon has been discovered in only a few forages. Where apomixis does exist, the forage breeder must find compatible sexual plants in order to manipulate it. Generally less than half of the hybrids produced will be apomictic. For more than 15 years, we have been trying to develop a superior bahiagrass hybrid that would be apomictic. The percentage of apomictic hybrids has been very low, and the one outstanding apomictic hybrid deve-

loped produces too little seed for commercial propagation.

Genetic manipulation of apomixis, the only method we have to date, is wasteful. A method of temporarily making apomictic plants sexual would be worth millions of dollars to breeders who must improve them genetically.

Dioecious Plants. Buffalograss, *Buchloe dactyloides* and Texas bluegrass *Poa arachnifera* are examples of dioecious pasture plants. With such species, hybrid seed could be readily produced by harvesting all seeds from production fields vegetatively planted to alternate rows or blocks of the best combining male and female clones. A rapidly spreading species like buffalograss should be well suited to this type of hybrid-seed production. The search for a good seed-producing female clone and a male that would give the desired combination of characters and maximum heterosis would seem to be a fruitful approach to the genetic improvement of such species. Practicable methods of establishing the seed field could be the bottleneck in the commercial production of hybrid seed.

Self-Incompatability. Highly self-incompatible clones can be found in many perennial grass species. Out of several thousand space plants of Pensacola bahiagrass, we isolated superior self-incompatible, cross-compatible clones 14 and 108, the parents of 'Tifhi-1' (4). 'Tifhi-1 Pensacola' bahiagrass seed was produced by harvesting all seeds from fields vegetatively planted to alternate strips of superior self-incompatible, cross-compatible clones 14 and 108. Over a 4-year test period, duplicate Tifhi-1 pastures produced 460 pounds of liveweight gain per acre annually, compared with 390 pounds for the Pensacola bahia check. One commercial seed field was established. Hybrid seed could have been produced for many years by merely harvesting all seeds produced in the field. Clones 14 and 108 would produce more seed than common Pensacola. Tifhi-1 and Tifhi-2 Pensacola bahia failed due to lack of a practicable mechanical method of planting seed fields and lack of promotion.

High-yielding self-incompatible clones of bermudagrass, *Cynodon dactylon* were isolated and tested in diallel crosses for specific combining ability (7). Over a 3-year period, plots established from seed (produced by the mutual pollination of the best pair of these self-incompatible, cross-compatible clones) yielded as well as vegetatively propagated plots of the best clones. Seed fields could have been easily established to alternate strips of these grasses, but the selected clones did not produce high enough seed yields to make commercial seed production profitable.

Cytoplasmic Male Sterility. Cytoplasmic male sterility will probably be discovered in all species. Its use in the production of the successful sorghum-sudangrass hybrids could be duplicated for perennial forages. Once a forage breeder has developed a good cytoplasmic male-sterile stock and its maintainer (it would not need to be an inbred), he would need only to test the forage-yield performance of single crosses involving unrelated males. The male parent would have to shed adequate amounts of pollen but would not need to restore fertility. A male parent that did not restore fertility would be much preferred, because it would greatly reduce the pest potential of the hybrid.

Pollinating our cytoplasmic male-sterile annual pearl millet with pollen from the perennial tetraploid 'Merkeron' napiergrass has produced a sterile triploid with excellent forage traits and immunity to rust (10). In the tropics, and even at Tifton in some years, the hybrid would be a perennial. The hybrid seeds, like pearl millet, would be excellent for planting pastures. Seed fields would have to be planted vegetatively to widely spaced strips of the perennial Merkeron napiergrass. Between these strips would be planted at the proper time the female parent 'Tift 23DA' pearl millet. The strips of the napiergrass could be planted with a sugarcane planter. The width of spaces between the rows would have to be established experimentally. Because napiergrass is a short-day plant and does not flower until October, seed production would have to be located in tropical areas free from winter frosts. The potential for this hybrid is great, but the bottleneck is again seed production.

Chance Hybridization. The chance-hybrid or first-generation synthetic technique used in the production of 'Gahi-1' pearl millet seed has potential as a method of producing hybrid seed of cross-pollinated perennial forages. Gahi-1 pearl millet seeds are produced by harvesting all the seeds from a field planted with a mixture of equal number of pure live seeds of four inbred lines that flower at the same time and give high yielding hybrids in all possible combinations. Since there is no self-incompatibility in these lines, the seed harvested is a mixture of 75 percent of the six possible single crosses and 25 percent of selfs and sibs of the four inbred lines. Only this syn-1 seed can be Gahi-1 seed, because substantial vigor is lost in going to advanced synthetic generations (5). Gahi-1 yields as well as the double cross involving the four inbred lines and has consistently out-yielded common millet by 50 percent (1). Many years ago we demonstrated this technique would also work with sudangrass (6). I do not believe the parental lines would require much, if any, inbreeding. They would need to be unrelated and would need to be selected for yield on the basis of their yield performance in diallel crosses.

Mass Selection. Preliminary tests indicate that we have increased forage yields of Pensacola bahiagrass by using four cycles of restricted mass selection. In each cycle, superior plants were chosen from a space-planting of approximately one thousand plants by weighing each plant and selecting the best individuals in a grid system that included 25 plants per unit. Culms were harvested from these plants when they were ready to flower, and were placed together in buckets of water in isolation. As they flowered, they were agitated to insure excellent crossing between all heads. Seeds harvested from these heads were used to plant the next generation. It remains to be seen whether the yield increase realized can be retained during several generations of seed increase if selection pressure for yield is released.

Amphidiploids. Amphidiploids result when the chromosome numbers are doubled in a hybrid containing genomes of nonhomologous chromosomes from unrelated diploid parents. Here, there is little or no synapsis between the chromosomes in the hybrid, and high sterility is expected. Doubling the chromosomes in such plants should result in fertility and might be expected to fix any heterosis carried in the original hybrid. Many important economic plants, including tobacco and wheat, originated in this manner. The extent to which breeders may use this method to fix heterosis awaits further study.

Synthetics. The possibility of making use of heterosis through the development of synthetic varieties should not be overlooked. It is possible to describe plant material from which synthetics showing considerable heterosis could be developed. Perhaps the ideal situation would call for a number of highly cross-pollinated, high-yielding parents capable of producing F_1s whose yields are considerably above the checks in most, if not all, combinations. In most schemes for using synthetic varieties, several generations elapse before the variety reaches the general public. By this time, considerable heterosis has been lost, and a ceiling has been established. Tysdal et al. (11), commenting on the use of synthetics in a breeding program, said, "Not only would F_1 hybrids have a yield advantage, but it would be easier to 'fix' other desirable characters than in a synthetic. For these reasons, breeders of alfalfa and other forage crops should thoroughly investigate the possibilities of utilizing F_1 hybrid vigor commercially."

Hybrid Vigor in Plant Improvement. I have not tried to describe all the known methods that have been suggested for producing hybrid forages. Young scientists who believe that there is a potential for hybrid perennial forages that cannot be realized otherwise will develop methods better than the best we know today. But they will do this only if they have the faith to believe that it should and can be done.

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BREEDING FORAGES RESISTANT TO INSECTS

By T. H. Busbice

There has been a tendency in the past few years to grab the spray gun when an insect pest appears. However, the use of insecticides is not the best solution to insect problems on forages. Insecticides are an additional cost to the livestock industry, but, more important, insecticide residues find their way into the meat and milk that we, and our children, consume. Our growing concern for the protection of health and environment demands that we find a better way of controlling forage insects.

When one is first introduced to the idea of insect resistance in plants the reaction is nearly always one of skepticism. I observe this reaction when I mention the subject to an acquaintance who is not familiar with this aspect of agriculture. Once, in response to the question "What do you do for a living?", I painstakingly described our breeding for alfalfa weevil resistance. I was rebuffed with the retort, "I would spray 'em, if it were me." Yet, plant resistance to insects is the natural state; if it were not so, the plant kingdom would have been destroyed eons ago. Extreme susceptibility occurs only sporadically at, what one might call, "the leading edge" of a continuing evolutionary process involving plants and insects. But, when our important crops are threatened by insects we cannot afford to wait for evolution to do its work, and the selection process must be accelerated by breeding.

Nature of Resistance

Painter (12) has successfully divided insect resistance into three parts:

1. Nonpreference for food, oviposition, or shelter.
2. Antibiosis of plants that adversely affects growth and survival of the insect.
3. Tolerance of the plant to insect attack.

More than one kind of resistance can operate simultaneously. When nonpreference becomes so strong as to cause starvation of the insect, the effect is antibiotic.

Examples of Breeding Forages Resistant to Insects

Fall Armyworm. Pearl millet is an important annual forage grown in the Southern USA. The fall armyworm, *Spodoptera frugupirda*, is a serious insect pest of pearl millet. Leuck et al. (7) screened 1436 inbred lines of millet in a greenhouse by infesting 3-day old seedlings with large numbers of laboratory-reared 1st-instar larvae. After five days resistance was rated for amount of defoliation. Fifty-eight lines were rated as being nonpreferred by the larvae. One line showed antibiotic reaction. Leuck (5) described the resistance as extreme nonpreference or antibiosis. Also, Leuck (6) grew the susceptible

pearl millet variety 'Gahi' in the greenhouse under differing fertilization regimes. Plants grown on fertilizer-deficient media showed resistance to the fall armyworm while plants grown under balanced fertilization showed susceptibility. He thereby demonstrated the importance of testing plants under favorable environmental conditions to obtain a true expression of resistance or susceptibility.

Bermudagrass has become an important forage species for the South. The fall armyworm is a pest when climatic conditions become favorable for the development of larvae. Leuck et al. (8) screened 441 bermudagrass clones for resistance to the fall armyworm in a greenhouse by infesting the plants with large numbers of larvae when the plants were 8 to 10 inches high. When some of the clones were completely defoliated, all entries were rated for damage. The test showed feeding preference among clones, and three clones were rated resistant.

Spittlebug. The two-lined spittlebug, *Prosapia bicincta*, sporadically inflicts severe damage to bermudagrass, varieties in the Southeastern USA (14). Symptoms of injury are initial chlorotic streaking of leaves, later coalescing to produce brown leaves. Spittlebug populations can increase rapidly under some conditions and entire fields can be completely browned-off. Damage results from a toxicgenic substance injected into plant stems as the sucking insect feeds. The vascular tissues transport the toxin up and down the stems and into the leaves causing loss of chlorophyll and death of mesophyll parenchyma cells. The greatest damage usually occurs in years with high spring and summer rainfall, however, the insects are present every year causing some damage. The spittlebug toxin seems to have little direct adverse effect on the underground parts of the plant, but root reserves are reduced because of damage to leaves. The spittlebug damages bermudagrass by reducing available forages and by reducing future production and persistence. Taliaferro, Leuck, and Stimmann (14) evaluated 398 clones of bermudagrass for resistance to the spittlebug by placing several field-collected adults on each clone in a greenhouse test. Differences in clonal reaction began to appear after 2 or 3 days. After 7 or 8 days some clones were severely damaged and all clones were rated for resistance. Nineteen clones were rated as highly tolerant. A tolerance mechanism, which enables some clones to withstand spittlebug toxin, appeared to be the basis of resistance.

Sod Webworm. Kentucky bluegrass is used for turf and pasture. Sod webworm (*Crambus* spp.) injury to Kentucky bluegrass is a serious problem in Kentucky. Buckner et al. (2) evaluated several strains of bluegrass in a field test and in a laboratory preference experiment. In general, Kentucky-common varieties showed less damage than varieties bred outside of Kentucky, indicating that sod webworm activity in Kentucky had resulted in natural selection for resistant types. Some selected strains consistently showed less injury than Kentucky common, suggesting that it might be possible to breed varieties with high resistance. Feeding trials and chemical evaluation failed to reveal the nature of resistance.

Sweetclover insects. The feeding of overwintered adults of the sweetclover weevil, *Sitona cylindricollis*, on the emerging seedlings of sweetclover sometimes makes it difficult to establish stands. Gross and Stevenson (4) evaluated nineteen species of *Melilotus* for field resistance. *M. infesta*, an annual, was immune. The remaining 18 species showed minor variation in resistance, and all were classified as susceptible. The authors expressed a concern for the probable difficulty of transferring the weevil resistance from *M. infesta* to commercially grown sweetclover species, *M. officinalis*. Manglitz and Gorz (9) found no relationship between coumarin content in sweetclover and weevil feeding.

The sweetclover aphid Therioaphis riehmi can cause seedling mortality (10) of sweetclover. Resistance has been found in many sources of this crop. This resistance seems to be of the nonpreference type which is sufficient to cause the insect to starve. Resistance is evaluated primarily by the mass infestation of young seedlings in controlled conditions. This method permits the handling of a large number of plants. Susceptible seedlings are killed by aphid feeding. Resistance is controlled by a single dominant gene.

Alfalfa Insects. For a review of breeding alfalfa for insect resistance I refer you to the chapter by Sorensen, Wilson, and Manglitz in the alfalfa monograph (13).

The spotted alfalfa aphid, Therioaphis maculata, is the most destructive insect pest of alfalfa in the USA: however, it is not a problem east of the Mississippi River. In rainfall-deficient areas of the West, plants may be stunted, defoliated, and stands killed from aphid injury. Resistant plants are found in many sources of alfalfa, but they are more frequent in Turkestan strains. Highly resistant varieties have been developed which are sufficiently free of aphids to provide adequate control of the insect. Some resistant varieties are Moapa 69, Zia, Cody, and Kanza. Resistance is highly heritable and seems to be related to extreme nonpreference or antibiosis. Selection can be done under controlled conditions and induced infestation.

The pea aphid, Acyrthosiphon pisum, is probably the most destructive alfalfa insect worldwide and causes some damage in the Upper South in the USA. Resistance to the pea aphid is highly heritable and controlled by a single dominant gene. Selection can be practiced under controlled conditions and induced infestation. Some resistant varieties are Washoe, Apex, Dawson, Mesilla, Kanza, and Team.

The meadow spittlebug, Philaenus spumarius, causes stunted growth of alfalfa in the spring in the Upper South and Midwest USA. The meadow spittlebug deposits her eggs in smallgrain stubble in the fall and the eggs hatch in the spring. The nymphs live in a frothy substance called a spittle mass. A single mass may contain from 1 to 30 or more spittlebugs. 'Culver' is a variety bred specifically for resistance to the spittlebug. It is said to be relatively nonpreferred, moderately antibiotic, and highly tolerant to the spittlebug. Culver shows less than one-half as much damage as other varieties.

The potato leafhopper, Empoasca fabae, causes extensive damage to alfalfa in the USA, particularly in much of the South. Injury is characterized by stunting of the plant and yellowing of the leaves. Varieties resistant to leafhopper yellowing are Cherokee and Weevlchek, but these varieties are, nevertheless, stunted. Resistance to yellowing is highly heritable. My observations on spaced plants suggest a negative relationship between resistance to yellowing and vigor (particularly, recovery after cutting). Therefore, I have decreased my emphasis of selection for resistance to leafhopper yellowing. A better understanding of the stunting effect of leafhopper feeding is needed to develop selection criteria for resistance to leafhopper stunting.

The alfalfa weevil, Hypera postica, was introduced into the Eastern USA in the early 1950's and rapidly increased in numbers and destructiveness. It is now the most serious insect pest of alfalfa in the Southern USA, and also it is becoming a serious pest of white clovers. Alfalfa fields can be completely defoliated by larval feeding in the spring.

Dr. C. H. Hanson began a breeding program for resistance to this pest in North Carolina in the late 1950's by selecting adapted plants from a breeding nursery which showed less larval feeding than surrounding plants. He combined

these plants into a breeding strain which we have come to call the "Starnes strain", reflecting the name of the selection site. We have evaluated several hundred varieties and foreign introductions (3), but the Starnes strain is the only source of germplasm that has consistently shown a resistance reaction to the weevil in North Carolina. The variety 'Team' was developed from the Starnes strain through recurrent cycles of selection in North Carolina and Maryland. We have developed other varieties, now in the experimental stage, from the Starnes strain which show greater resistance to the alfalfa weevil than does Team. See Table 1. The experimental MSHp6FAN4W4 had 5 generations of field selection for resistance and the experimental NCW20 had 6 generations of field selection.

TABLE 1.--Weevil Damage and Dry Matter Yield at First Harvest.

Spring 1973			
	No insecticide used		Weevil controlled by insecticide
Alfalfa variety	% defoliation**	Ton/acre	Ton/acre
NCW20*	37.5	1.16	1.31
MSHp6FAN4W4*	48.3	0.91	.97
Team*	55.8	0.73	.87
Saranac	69.2	0.64	.79
Weevlchek	78.3	0.49	.96
Cherokee	80.0	0.51	.99
LSD .05	4.8	0.15	0.17

* Developed by recurrent selection in Starnes strain.
** Visual estimate.

The resistance of the Starnes strain seems to be of the tolerance type. Tolerance mechanisms appear to involve morphological and physiological traits such as early spring vigor, heavy stem terminals and auxillary branching. While extensive laboratory and greenhouse evaluations for nonpreference and antibiosis have been conducted by the ARS and cooperating state experiment stations, these types of resistance have not been elucidated. While immunity to the alfalfa weevil is known to exist in some Medicago species, no serious effort has been made to transfer this resistance to alfalfa (M. sativa).

I have not attempted to exhaustively review all reasearch on breeding forages for resistance to insects. Other breeding programs have involved resistance to grasshoppers, grass grubs, grass scale, European Corn Borer, Corn Earworm, Alfalfa Seed Chalcid, lygus bug, tarnish bug, and others. A new turf variety of St. Augustine grass, 'Floratam', has been released recently that has high resistance to the cinchbug (personal communication with R. L. Duble, Texas A & M University). St. Augustine grass is sometimes used as a forage.

SUMMARY

Breeding forages resistant to insects has been highly successful in many instances. More research of this kind is needed.

Insect resistance can be considered to be very stable. However, we have one example where the evolution of the insect has caused a previously resistant variety to become susceptible. New strains of the spotted alfalfa aphid have arisen which are able to attack previously resistant varieties. This situation has been resolved by the breeding of new varieties resistant to the new strains of the aphid (13).

Insect resistance is usually due to subtle factors. The question is always asked, "If the forage is resistant to insects, will the cows eat it?" Generally, insect resistance has not lowered the quality of forages. Indeed the quality of forages often has been increased by reducing insect feeding, and by reducing insecticide residues of chemicals used to control the insect. The effect of resistance genes on the quality of forages usually is not discernible.

Selection for insect resistance is being conducted both in the field under natural infestation, and in the greenhouse and laboratory under induced infestation. Induced infestation under controlled conditions may be effective when natural insect population buildup and attack is sporadic and uncertain. Also, under controlled conditions several generations of an insect can be reared within a year when only one would occur naturally. Selection under controlled conditions seems to be most effective when the resistance reaction is strong or of the antibiosis type.

Field selection for resistance is effective when heavy and reliable insect infestations occur. Field selection is most important when resistance is due to tolerance mechanisms involving the morphology and physiology of the plant. In such instances genotypes x environment interactions may be important, and the field environment is needed to evaluate resistance.

Research on genetic resistance of forage crops to insects likely will succeed when sufficient efforts are made. Such research is complicated by the complexities of both the crop and the insect pest. More rapid results will be obtained when plant breeders and entomologists work together as a team to solve the problem. Much of our past research on insect resistance has been piecemeal and discontinuous. This approach is wasteful. Sufficient time (usual several years) and money must be allocated to solve the problem, and the problem is not solved until resistant varieties are in the hands of farmers.

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DERIVATION AND USE OF HAPLOIDS IN FORAGE BREEDING

By E. T. Bingham [1]

Haploid plants have the same chromosome number as gametes of normal individuals of the species. They arise by parthenogenesis of post-meiotic sex cells and may be thought of as living gametes. Their occurrence among angiosperm plant families, including grasses and legumes, is widespread, suggesting haploid isolation should be possible in any desired species. In general, haploid plants have reduced vigor, smaller and finer leaves, and low fertility. However, fertility as females in crosses is almost always sufficient to permit their use in research, whether they are haploids of diploids or polyploids. The most commonly cited use of haploids is doubling of the chromosome number to produce complete homozygosity when they are from diploids or allopolyploids, and increased homozygosity when they are from autopolyploids. However, haploids of polyploids have a multiplicity of additional uses. In alfalfa, which behaves as an autotetraploid, these include diploidization of marker genes, breeding at the diploid level, direct gene exchange with wild relatives of alfalfa, development of stocks with known genotypes to test breeding theory, and cytogenetic analyses, as well as others.

Haploids among forages have most commonly been found as members of twin seedlings. They also occasionally occur spontaneously. However, these methods of obtaining haploids are rather inefficient, and hybridization techniques using wide crosses or genetic markers have greatly increased the efficiency of producing haploids in alfalfa and some other species. Another culture would seed to offer the greatest potential in obtaining haploids, but thus far, this method has been applied in only a few species.

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IRRADIATION AND MUTATION BREEDING: ACCOMPLISHMENTS AND ROLE IN A PRACTICAL PLANT BREEDING PROGRAM

(Abstract)

By Milton J. Constantin [1]

Plant breeding can be defined as evolution guided by man. As such, plant breeding is dependent on genetic variability, hybridization that produces recombinations of genes, and selection of desirable plant types. The plant breeder has traditionally controlled hybridization and selection in an effort to exploit naturally occurring genetic variability, the product of spontaneous mutations and natural selection.

Muller and Stadler demonstrated in the late 1920's that the mutation rate in Drosophila and barley was increased significantly by irradiation. This placed under man's control the creation of genetic variability in species of interest. In the minds of some researchers, mutation induction offered a short-cut substitute for conventional plant breeding. Several decades later, mutation breeding was being referred to as a gimmick of the atomic age, a breeding short-cut that provides much and delivered little.

We need to consider the tremendous change in viewpoint toward mutation breeding and its current status. After World War II, sources of ionizing radiation and radiomimetic chemicals became increasingly available to plant breeders. Plant breeders enthusiastically tried mutation induction as a means of fulfilling practical objectives. Much of their effort was fruitless because their knowledge of how to induce, recover, and utilize mutations was rudimentary, while their expectations were monumental. The lack of major positive results led to a pessimistic attitude. A number of research centers, however, continued to study the phenomenon of mutation induction, techniques of mutagenic treatments and the recovery of mutations, and the use and value of recovered mutants in a plant-breeding program. A by-product of this fundamental research was the release of many improved varieties of crop plants. Gradually, mutation breeding acquired the status of an accepted plant-breeding tool that is highly effective in certain cases. Mutation breeding is a functional part of, and not a substitute for, conventional plant breeding.

Mutation induction presents no cause for controversy. Induced mutant germplasm is essentially equal in all respects to naturally occurring germplasm. Furthermore, mutant germplasm has the added advantage that man can impose selection pressure of an agricultural nature rather than natural selection. To use mutation induction effectively, the plant breeder must understand mutation induction techniques and potential, and he must also be able to judge

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those cases in which mutation induction offers advantages over other techniques. The latter requires considerable knowledge of genetic variability available in nature and the inheritance pattern (breeding behavior) of the trait in question. In certain cases, it might be expedient to use both mutation induction and hybridization. In other situations (plants with obligatory asexual reproduction for example), mutation induction may offer the only hope for an increased range of genetic traits.

Mutation induction methods are numerous, and many are not completely resolved. It appears that mutation induction can play an important role in the area of plant breeding in which natural selection has not influenced genotypes or eliminated genotypes detrimental to survival in nature but of value to man in an agricultural context. Examples include increased content of specific amino acids, changes in the distribution of protein in various plant parts, lack of photorespiration, and photo- and thermo-insensitivity.

Thus, mutation induction should be regarded as a valuable plant-breeding tool to be used in conjunction with other established procedures. Mutation induction can be used successfully to extend the genetic base in crop species, including the re-creation of specific genetic traits that have been lost through natural selection, although it cannot be expected to give rise to gene complexes.

METHODS AND TECHNIQUES FOR DETERMINING COMBINING ABILITY AND THEIR USE IN FORAGE BREEDING

By W. A. Cope [1/]

INTRODUCTION

"Combining ability" is an especially popular topic in research on forages. The term "combining ability" has different meanings for different people, but the definition of Sprague and Tatum (23)[2/] delineating general combining ability (GCA) and specific combining ability (SCA) is now commonly used. GCA denotes the average performance of a line or genotype in hybrid combinations. SCA designates those cases in which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved.

Such definitions seem to reflect the breeder's desire to identify complex biological phenomena in terms of a single parameter. In estimating such parameters we must remember certain limitations. Results can be no better than the genetic models used and the information fed into the models.

Combining ability can be estimated simply by partitioning of the means. Sprague (18) outlined such a procedure. The method is applicable only when gene frequencies are known, as in F_2 or similar populations. Also, the technique may provide evidence for the existence of different types of gene action, but it provides no evidence of their relative importance. However, Sprague indicated that a more generally useful method for estimating type of gene action is provided by variance component analysis. Thus, the concepts of combining ability that we want to consider here represent an extension of quantitative genetics.

We will here review a few definitions pertinent to our discussion.

Additive variance: effects of substituting one allele for another at individual loci.

Dominance variance: the within—locus variance remaining after subtracting the additive.

Epistatic variance: that portion of the total genetic variance that remains after subtracting the total within-locus variance.

Genetic variance, one locus: additive, σ^2_A and dominance, σ^2_D.

Genetic variance, two loci: $\sigma^2_{A2} + \sigma^2_{D2}$ + interaction variance (σ^2_{AA}, additive X additive; σ^2_{DD}; σ^2_{AD}, etc.).

Falconer (16) concludes that interactions at more than two loci contribute so little variance that they can be ignored. Other variances from genetic experiments can be genotype X environment interactions; environmental (replications, locations, and time); and error variance, σ^2_E.

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2/ Underlined numbers in parentheses refer to items in "References" at the end of this paper.

Quantitative geneticists have emphasized the importance of fixable genetic variance (σ^2A and σ^2AA) as contrasted to dominance and epistatic variance. There is also the tendency to equate GCA with fixable variances and SCA with non-fixable variances. Theoretically this may be sound, but in practice it may not be possible to get an estimate of simple additive effects. Falconer (16) says, "The concept of additive variance does not carry with it the assumption of additive gene action; and the existence of additive variance is not an indication that any of the genes act additively (i. e., show neither dominance nor epitasis). No assumption is made about the mode of action of the genes concerned. Additive variance can arise from genes with any degree of dominance or epistasis, and only if we find that all the genotypic variance is additive can we conclude that the genes show neither dominance nor epistasis."

Review of Some Basic Concepts

The review of Dudley and Moll (14) provides a useful summary of the use of genetic variances. Plant breeding can be divided into three stages, (1) creating a pool of variable germplasm; (2) selecting superior individuals or populations; and (3) using the selections to create a variety.

Genotype X environment interactions may be large. If so, the more diverse the environmental population sampled in a given test (reps, locations, years), the smaller the estimate of genetic variance since more of the genotype-environment interaction is removed from the estimate of genetic variance. The choice of a particular population from the germplasm pool will depend on the mean performance of the population and the genetic variance within the population. Reliable comparisons of genetic variances require rather large samples of progeny from each population and extensive testing over environments if genotype-environment interaction is important. As an example, work at North Carolina State University, Raleigh, with yields of corn suggests that at least 256 full sib families are necessary to obtain reliable estimates of additive and dominance variance and that these families need to be grown at least two years at two locations.

Because large numbers of progenies are required to obtain reasonable estimates of genetic variance components, the question of appropriate experimental designs is often raised. When the quantities of interest are variances rather than means, designs such as the lattices which confound genetic and environmental differences among means are not satisfactory. The replications-in-block design suggested by Comstock and Robinson (9) or a blocks-in-replication design is generally satisfactory. However, the mating design must be such that sets of progenies can be randomly assigned to the blocks in a way that will allow an independent estimate of the variances of interest from an analysis of each block.

Designs and Analyses

An appropriate mating design is required for estimating additive and non-additive genetic variances. Cockerham (8) classifies mating designs as one, two, three, or four factor designs, depending on the number of ancestors per progeny over which control is exercised. Common designs such as the diallel cross, designs I, II, and III of Comstock and Robinson (9), are two-factor designs. Triallel and quadriallel crosses are three- and four-factor designs. A set of half-sib families or polycross progenies would constitute a one-

factor design. A one-factor design is sufficient to detect the presence of genetic variability. For separation of additive and dominance variance (assuming epistasis is absent), a two-factor design is necessary. For estimation of epistatic variance a more complex design or combination of designs is required.

Certain assumptions must usually be made for cross-pollinators or for self-pollinators where the designs appropriate for cross-pollinators are used. Some of these are:

(1) Populations are assumed to be at random mating equilibrium.
(2) Normal diploid and solely Mendelian inheritance.
(3) No environmental correlations among progenies.
(4) Progenies are not inbred and can be considered random members of some noninbred population.
(5) Linkage equilibrium.
(6) The assumption of diploid inheritance includes regular amphidiploids and can be modified to include autotetraploids.

It is recognized that all the above assumptions are seldom met completely. Limitations arising from failure to meet certain of these conditions have been treated in the literature.

Partitioning of gene action into additive and non-additive effects is necessary for estimating combining ability. As indicated above, two-factor or more complicated mating designs are necessary for partitioning. However, one-factor designs can be quite useful in the initial stages of a breeding program where one surveys the genetic material available. Some of the designs commonly used or discussed in the literature will be given here.

Designs I, II, and III (18) were not intended for estimating combining ability, but they meet the requirement for estimating combining ability in that genetic variance is partitioned into additive and nonadditive portions.

Design I. For field testing, the progenies are grouped into *mn* sets, and each set may be considered a unit in a randomized complete block experiment.

Material: Random F_2's from a cross between inbred lines.

Matings: Cross each F_2 (*m*) to a set of *n* females.

TABLE 1.--Analysis of variance for design I

Sources of variation	Degrees of freedom	Expected mean squares
Sets (*S*)----------------------	*s*-1	
Replication/sets (*R*)----------	*s*(*r*-1)	
Males/set (*M*)-----------------	*s*(*m*-1)	$\sigma_2^2 + r\sigma_f^2 + rn\sigma_m^2$
Females/males/sets (*F*)--------	*sm*(*n*-1)	$\sigma \quad {}^2$
Plots within replications-----	*s*(*mn*-1)(*r*-1)	$\sigma^2 + r\sigma_f$

Partitioning of the genetic variances is as follows:

$$\sigma_m^2 = 1/4\ \sigma_A^2$$

$$^2_f = 1/4\ \sigma_A^2 + 1/4\ \sigma_D^2$$

Design II. Applicable to multiflowered plants.

Material: Random F_2's from a cross between inbred lines.

Matings: A set of *mn* progenies comes from all possible matings of

randomly selected m males with n females.

The sets are maintained intact in the units of the field design.

Partitioning of the genetic variance is as follows:

$$\sigma^2_{m} = 1/4\ \sigma^2_{A}$$

$$\sigma^2_{f} = 1/4\ \sigma^2_{A}$$

$$\sigma^2_{mf} = 1/4\ \sigma^2_{D}$$

Design II is actually a partial diallel, since all possible matings are made within sets of parents.

Design III. The field test consist of s sets of n pairs of progenies.

Material: F_2 or more advanced generation progeny of crosses between inbred lines.

Matings: Pairs of backcross progenies are made by crossing individual F_2 male plants with the parents of the original cross. A set contains two n progenies (representing one original cross).

Design III is not used extensively, and it is easy to misuse. To obtain valid estimates the gene frequency must be 0.5, and there must be no epistasis.

The above examples from Designs I, II, and III each represent only one experiment or environment. Repetition in a number of environments is essential for valid estimates.

Diallel crosses. According to LeClerg (18) the diallel cross mating system was first discussed in genetic literature as early as 1919. Sprague and Tatum (23) used the diallel cross to develop the concepts of general and specific combining ability. A number of variations have been used, including incomplete diallels and unbalanced diallels in which unequal numbers of crosses for different parents occur. The 1956 paper of Griffing (19) has received wide attention and is reviewed breifly here.

Four experimental methods are discussed, (1) parents, one set of F_1's and reciprocal F_1's; (2) parents, one set of F_1's; (3) one set of F_1's and reciprocals; and one set of F_1's.

He considers two models, designated models I and II by Eisenhart (15). In model I variety and block effects are considered constants. The experimental material is to be regarded as the population about which inferences are made. We are particularly interested in estimating combining ability effects and computing appropriate standard errors for differences between effects.

In model II variety and block effects are both considered random variables. The assumption is that we are dealing with random samples from some parent population. Inferences are to be made about the parent population. We are interested in estimating the genetic and environmental components of the complex population variance.

The proper interpretation of the combining ability effects and variance depends on the particular diallel method, the assumptions regarding the experimental material, and the conditions imposed on the combining ability effects. Without going into detail, we will consider one of the four methods (table 2).

TABLE 2.--Analysis of variance for method 4 (Griffing, 1956)

Source	df	Mean squares	Expectations of mean squares 1/ Model I	Model II
General combining ability	$p-1$	M_g	$\sigma^2 + (p-2)(\frac{1}{p-1}) \Sigma_g^2$	$\sigma^2 + \sigma_s^2 + (p-2)\sigma_g^2$
Specific combining ability	$P(p-1)/2$	M_s	$\sigma^2 + (\frac{2}{p(p-3)})\Sigma\ \Sigma_s^2$	$\sigma^2 + \sigma_s^2$
Error	M	M_e	σ^2	σ^2

1/ To test GCA effect, use M_g/M_e. To test SCA effects, use M_s/M_e.

Other designs. For self-pollinators from which random-mating populations cannot be readily developed the nested designs described in detail by Cockerman (8) are well suited for estimation of genetic components of variance. In such designs and F_2 progeny is grown, and one or more advanced generations are produced from a certain number of F_3's from each of the F_2's. In the field test, all generations may be grown and the nesting effect obtained by keeping all progeny of a given F_2 together in one set. With large numbers of F_2's, the sets of F_2 progenies should be blocked into smaller groups to reduce error. The report of Brim and Cockerham (3) concerning soybeans is an excellent example.

Specific Examples

A partial dialled study by Dudley et al. (12) provides an excellent example of the procedure for a particular mating design, the interpretation of results, and some of the limitations. Four blocks of clones from the variety Cherokee were used, representing 17, 18, 19, and 20 clones. Each clone was crossed with four other clones within a block. The 148 crosses and 74 clonally propagated parents wre planted in a blocks-within-replicates design, three replications at each of two locations. The genetic model assumed tetrasomic inheritance. Appropriate analysis of variance and covariance gave estimates of clonal variance, σ_c^2; GCA, σ_g^2; SCA, σ_s^2; and covariance of parent and offspring, σ_{po}. Partitioning of the respective sources is as follows

$$\sigma_c^2 = \sigma_A^2 + \sigma_D^2 + \sigma_T^2 + \sigma_F^2$$

$$\sigma_g^2 = 1/4\ \sigma_A^2 + 1/36\ \sigma_D^2$$

$$\sigma_s^2 = 1/6\ \sigma_D^2 + 1/12\ \sigma_T^2 + 1/36\ \sigma_F^2$$

$$\sigma_{po} = 1/2\ \sigma_A^2 + 1/6\ \sigma_D^2$$

Where σ_A^2= additive gene action, σ_D^2= two-allele interaction per locus (digenic), σ_T^2= three-allele interaction per locus (trigenic), and σ_F^2= four-allele interaction per locus (quadrigenic).

From these expectations, the following estimation equations were derived:

$$\sigma_A^2 = 6\ \sigma_g^2 - \sigma_{po}$$

$$\sigma_D^2 = 9\ \sigma_{po} - 18\ \sigma_g^2$$

$$\sigma_T^2 = 48\ \sigma_g^2 + 18\ \sigma_s^2 - 23\ \sigma_{po} - 0.5\ \sigma_c^2$$

$$\sigma_F^2 = -36\ \sigma_g^2 - 18\ \sigma_s^2 + 15\ \sigma_{po} + 1.5\ \sigma_c^2$$

Significant estimates of total genetic variance (σ_c^2), GCA (σ_g^2), and σ_{po}^2 were obtained for the traits measured. The lack of a significant estimate of SCA (σ_s^2) was attributed to the differences between coefficients in the above equations. The small fractions of σ_T^2 and σ_F^2 included in σ_s^2 may not have been large enough to allow detection in the analysis of variance, particularly if σ_F^2 was important.

The authors concluded that either the trigenic, quadrigenic, or epistatic variance was important. Estimates of narrow sense and broad sense heritability were, respectively, 22 and 73 percent. The authors encountered difficulties in obtaining all the desired crosses and suggested an alternative design using several small complete diallels and pooling sums of squares from each for estimation of σ_g^2 and σ_s^2. Note that in this study the GCA and SCA estimates were used for partitioning into gene effects.

The nested design for self-pollinators. An example of the nested design for self-pollinated crops is that of Cope and Moll (10) with sericea. The F_2 population from a single F_1 from a cross between widely different lines was grown. Then 3 F_3 plants from each of 80 F_2 plants were grown and seed harvested. Parent lines, F_2, F_2 in F_3, and F_3 in F_4 populations comprised the field plantings. The progeny of each F_2 comprised a set, and sets were blocked in 4 groups of 20 each in a replicated randomized block design. The analysis of variance provided the following partitioning of genetic effects:

$$\sigma_{2(3)}^2 = \sigma_A^2 + 1/4\ \sigma_D^2 + \sigma_{AA}^2$$

$$\sigma_{2(4)}^2 = \sigma_A^2 + 1/16\ \sigma_D^2 + \sigma_{AA}^2$$

$$\sigma_{3,\ 2(4)}^2 = 1/2\ \sigma_A^2 + 1/8\ \sigma_D^2 + 5/4\ \sigma_{AA}^2$$

Again we have a problem in estimating dominance effects because of small coefficients; this is seen in the large standard errors.

In this study low tannin was shown to be a simple recessive. However, the estimate of σ_D^2 was not larger than its standard error. Although not significant (smaller than the standard error), the dominance estimates for other traits were large relative to the combined estimates of σ_A^2 and σ_{AA}^2. This indicates the possibility that dominance is more important than it is often considered to be in such studies.

TABLE 3.--Estimates of genetic components of variance in sericea

Trait	Variance Component σ^2_A	σ^2_D	σ^2_{AA}	Heritability %
Tannin---------	3.2 ± 1.4	6.2 ± 7.0	0.55 ± 0.86	88
Spring yield---	38 ± 104	525 ± 598	81 ± 86	45
Fall yield-----	1,205 ± 1,165	5,803 ± 6,284	760 ± 917	60
Seed yield-----	108 ± 46	138 ± 260	-9 ± 35	57

There are two drawbacks to the general use of this kind of study. It is expensive in terms of time and resources, and it serves to evaluate only two inbred parents, a very small sample of what is needed. A more practical means of evaluating inbred germplasm would be to make crosses between large numbers of different inbreds and evaluated F_2 populations for superior performance. The use of a male-sterile character, such as reported by Brim and Young (4), could be even more useful. Male-sterile plants set a few seed through insect pollination, and they can be identified phenotypically. The use of distinctive markers could serve a similar purpose, as in the case of lupine where a small amount of insect pollination has been reported (17).

Numerous studies on combining ability in various forage crops could be reviewed here. However, many different crop species are represented by this group, and the opportunity for estimating and utilizing combining ability varies with each crop because of differences in crossing and self-fertility, and with the particular genetic system involved.

General Problems

For cross-pollinated crops, the variety developed by the breeder is usually a synthetic. If we view combining ability primarily in terms of variety yield, there are the problems of maintaining combining ability during the process of selecting superior genotypes (often with cyclic selection in a closed population) and of maximizing combining ability by the procedure used to produce the variety. It is not sufficient to measure performance in terms of some random or selected group of parents. The breeder must deliver a variety that is superior to the better commercial or commonly used varieties.

Problems associated with selection. Breeders generally tend to exploit the broad genetic diversity of cross-pollinated crops. Ideally, inbreeding should be kept to a low level in a cyclic program where selection for multiple traits is exercised.

The coefficient of inbreeding in diploids in succeeding generations of random mating was summarized by Falconer (16): $F = 1/2N$, where F = the coefficient of inbreeding and N = the number of intermating individuals. The coefficient of inbreeding is additive over generations in a closed population; the coefficient of inbreeding for a given generation is the sum of the coefficient for that generation and that for each preceding generation. Thus, in a closed cyclic selection population, the coefficient of inbreeding increases with each succeeding generation. Stringent selection that reduces the number of intermating individuals can results in a rapid rate of inbreeding.

In autotetraploids the rate of inbreeding is much less than with diploids, being only 1.6 for one generation of selfing. If we can assume that the co-

efficient of inbreeding for a given generation of random intermating is 1/4 N (non-inbred) the rate of inbreeding must still be an important factor in a selection program. Busbice and Wilsie (7) estimated the rate of inbreeding when selfing alfalfa on the assumption of interactions among multiple alleles. They found that the rate of inbreeding depression on forage yield, reported by Tysdal et al. (25), was greater than expected on the basis of estimated degree of inbreeding, especially in early generations of selfing.

Dewey (11) compared diploid and induced autotetraploid S_1 progenies of crested wheatgrass, Agropyron cristatum. The loss in forage yield of seven induced autotetraploid lines was 17.3 percent compared with 54.9 percent for their diploid counterparts. Dewey reviewed results from newly synthesized autotetraploids of crested wheatgrass, corn, Italian ryegrass, and alsike clover, indicating that these newly synthesized autotetraploids show a much lower degree of inbreeding depression than old natural autotetraploids such as alfalfa, orchardgrass, and crested wheatgrass, A. desertorum. He suggested that an accumulation of chromosome aberrations and unfavorable gene combinations in species buffered by autoploidy is a major cause of excessive inbreeding depression in natural autotetraploids.

It appears obvious that the breeder of cross-pollinated crops must take measures to counter the effects of inbreeding in a cyclic selection program in a closed population. Hanson (20) used relatively large numbers of selections per generation (80-100) in alfalfa and reported that vigor increased in 2 populations through 11 generations of phenotypic selection. A more practical procedure may be to use a number of smaller populations to select superior lines or clones. Selections from different populations should not be related by inbreeding during selection, and could be used to produce a synthetic variety to insure a minimum relationship among parental clones.

Synthesizing a Variety

In a recent report on combining ability in birdsfoot trefoil, Twamley (24) gave a brief review of work with synthetic varieties. The work of Tysdal, Kiesselbach, and Crandal in laying the groundwork for synthetic varieties was pointed out, indicating their hope that the high combining ability of selected Syn 0 parents would be retained in later generations. Twamley expressed the opinion that the synthetic method of breeding for improved yield did not live up to expectations. This opinion has been substantiated by a number of reports showing declining yield with successive generations of synthetics. Performance of synthetics beyond the Syn 1 generation is seldom superior to that of the better commercial varieties. Twamley assumes that in the synthetic approach to forage breeding, no attempt is made to differentiate between additive and non-additive types of gene action. He concludes that special emphasis should be placed on additive genes by selecting Syn 0 material not only on the combining ability of its components, but on their progeny's ability as well.

Busbice (5) has estimated the degree of inbreeding in successive generations of synthetics composed of numbers of Syn 0 parents varying from 2 to 64. He describes a synthetic variety as an expanding population consisting of few individuals in the Syn 0 and many individuals in advanced generations. When there are few individuals in the Syn 0, relatives will mate in advanced generations, resulting in inbreeding. Inbreeding results in changes from generation to generation, with the greatest change being from Syn 1 to Syn 2. From calculations based on the assumption of unrelated Syn 0 parents, Busbice (6) concluded that at least four parents are required to prevent excessive

inbreeding in advanced generations, and there appears to be little advantage to including more than 16 parents in a synthetic as long as they are non-inbred and unrelated. The coefficient of inbreeding, assuming random mating and no selfing, would never exceed 2 percent.

Hill et al. (21) developed sets of four=clone synthetics in two alfalfa populations. There was significant SCA for reaction to certain diseases, but little for yield. They concluded that in order to make use of nonadditive variance (or SCA), the alfalfa breeder should use narrow-based synthetics or even hybrids. Then only a portion of SCA would be used.

It is disturbing to read paper after paper on combining ability or other partitioning of genetic effects and find the authors concluding that one should concentrate on selecting for GCA. This conclusion may be because the writers consider SCA nothing more than the product of some unique epistatic gene combination that will be disrupted in the following generation. At this point it may be well to remember that best estimates of additive variance may not be clean; they may include effects of other types of gene action. It is beyond the scope of this discussion to consider the biological implications of changes in genetic systems. However, certain examples of effective long range selection programs should be mentioned. In a cyclic selection program with corn, Moll (22, and personal communication) has been able to accurately predict yield increases through 10 generations. Moreover, the genetic variance for yield did not decrease during these generations. Dudley et al. (13) reported that during seven cycles of selection in two germ plasm pools in alfalfa there were changes in genetic variances for leafhopper reaction (increase) and for rust reaction (decrease). The changes were considered to be due to changes in gene frequency for these traits with relatively high heritability. On the other hand, genetic variances and heritability values for spring growth and recovery ratings were similar between the two populations and among cycles within populations. Vigor was high enough that cycle 7 of one of the populations was released as the variety 'Cherokee'.

CONCLUSIONS

On theoretical and practical grounds, it appears unlikely that breeders of cross-pollinated forage crops will make any significant improvement in yield by standard methods of producing synthetics. Restriction to the application of additive genetic variance through long range cyclic selection in closed populations may be necessary in certain cases. However, it seems that breeders have a responsibility to utilize both GCA and SCA where the reproductive system of the crop permits. A practical objective would be to limit the seed production for farm use to the syn 1 or the equivalent in terms of inbreeding or disruption of epistatic gene combinations.

Several varieties have been produced which essentially meet this requirement. 'Tillman' white clover is a syn 2 of three single crosses among six unrelated clones. 'El-Unico' alfalfa from the Arizona Agricultural Research Station is a syn 2 from a blend of F_1 seed from two single crosses. If adequate seed could be produced in the syn 1, an acceptable level of combining ability might be achieved. It has been reported that an F_1 hybrid variety of alfalfa has been produced by a commercial seed company, by using male sterility. More recently Anderson and Taylor (1) have developed double-cross varieties of red clover by making use of the incompatability system. This may prove to be a very significant step in the development of new varieties.

Production of adequate seed for farm use at a level of heterozygosity not

less than that of the syn 1 may require some ingenuity on the part of the plant breeder. But with many crops it is not an unrealistic possibility in view of the benefits to be derived. Many plants can be cloned sufficiently for F_1 seed increase for synthetic production, as in the case of 'Tillman' clover. The use of sterile males and oppositional allele sterility mechanisms are other options that offer opportunity in many crops.

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PROTECTION OF THE GERM PLASM OF
FORAGE CROP VARIETIES

(Abstract)

By E. A. Hollowell [1]

Seeds of many old and new superior varieties of legumes and grasses are not being produced in sufficient volume for use on farms where adaptation would be possible. Unfavorable weather causes seed production in the southeastern states to be most frequently a by-product of other farming enterprises. In the West, climate favors large seed yields and good economic returns, but after a very few generations of seed increases under western conditions, breakdowns in adaptation occur in varieties bred for adaptation to eastern conditions.

The production and use of certified seed is the only known method of being sure that consuming farmers are getting seed true to variety name. Segments of the seed trade have added misleading prefixes to the names of certain reliable varieties of seed, disguising poor seed as certified seed. The Association of Official Seed Certifying Agencies has developed rules, regulations and procedures to protect the germ plasm of superior varieties during the different steps in seed certification.

The first attempt to plant eastern-bred varieties in the western States for seed increase was in the middle 1920's when Tennessee anthracnose-resistant (TAR) red clover seed was sent to Oregon. Its high contamination with noxious weeds and the undependable eastern market made it an abortive attempt.

A cooperative experiment among the Kentucky, Tennessee, Oregon, and Idaho State Experiment Stations and the Bureau of Plant Industry, U. S. Department of Agriculture, to grow and test six generations of TAR red clover under western conditions for comparative testing at the eastern locations was developed. After three generations of production in the West, significant changes in adaptation occurred and led to a limitation of generation in certified seed production.

Results of a recent experiment on the effect of temperature on the hybridization and selfing of white clover[2] indicate that under high temperatures, the ease and rate of successful interspecific hybridization may be greatly enhanced. Also the apparent genetic shift in factors of adaptation may be due to a high rate of selfing with a subsequent inbreeding depression. The study indicates that high temperature may be an important factor in the phylogeny of the *Trifolium* genus and is perhaps the reason why the center of origin of the

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1/ Agricultural Research Service, U. S. Department of Agriculture (retired).

2/ Gibson, P. B., and Chen, Chi-Chong. 1973. Success in hybridizing and selfing Trifolium repens at different temperatures. Crop Sci. 13(6): 728-730.

Trifolium spp. is in the Mediterranean and Asia Minor regions. An excellent review of temperature effects on self incompatability and cross-compatibility in plants is included in the results.[3/]

The plant breeder must continually sell through all means of communications the value of certified seed of adapted varieties. I believe that the first major item in any pasture and forage improvement program should be the use of certified seed of the best adapted varieties.

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EXTENSION RESPONSIBILITY IN MAINTAINING CERTIFIED SEED OF LEGUMES AND GRASSES

By E. A. Hollowell [1/]

This paper is nearly the same as the one I presented last year at the Breeders Session of this Conference. I have been asked to present it to you, the Southern Extension Forage Specialist Work Group. I believe that I can point out what is happening in the forage seed market. I will attempt to identify the needs in this field and assign responsibility for meeting those needs.

Present Problems with Certified Seed

The first step in any forage and pasture improvement program is the use of certified seed of superior adapted forage varieties. Supplies of certified seed of these varieties must be made available in sufficient quantities to plant the acres devoted to these crops.

What about these superior varieties, new and old? Are they being planted on farms according to their value? If not, what is happening?

May I cite a few examples. 'Kenwell' tall fescue was named and released in 1965. It has high resistance to *Helminthosporium* leafspot and foot rot and grows vigorously. Livestock producers claim that they do not like it. Very little seed is available. Since tall fescue is being extensively used for lawns in the northern part of the Southeastern United States, 'Kenwell' should be the variety widely used because leafspot is frequently a cause of thin stands of 'Kentucky 31', when seeded at heavy rates. But certified seed of Kenwell is not available at many retail stores, and what we get contains orchard grass that makes a miserable looking lawn. Is this an extension responsibility?

In the southern part of the region, we must use a reseeding or volunteering type of white clover since stands do not often survive the summer environment. 'Louisiana S-1' and 'Nolin' white are productive and reseed well. Noncertified 'Louisiana S-1' produced in Oregon has been widely sold throughout that part of the United States by the seed trade. It can be any nondescript common seed. Segments of the seed trade use the name of 'Louisiana S-1' as a sales gimmick to make a fast buck because they can undersell home-grown or certified seed by 15 to 25 cents per pound.

What State is challenging this practice? There is sufficient experimental evidence already available to warrant recommendations against using such seed. Have either the breeder or extension agronomist made such recommendations? We went through this situation years ago with both affidavit 'Grimm' and 'Ranger' alfalfa seed. We found that over 50 percent of seed sold as these cultivars was not true to variety name. The Federal Seed Act took action against such a

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1/ Agricultural Research Service, U. S. Department of Agriculture (retired).

classification and about a year ago, the group administering the Federal Seed Act indicated that they would act against such mislabeling if the State agency that handles the enforcement of State seed laws would request them to do so. Has this bee done? Who is responsible for the lack of action?

Great progress has been made in the development of superior cultivars of crimson clover. 'Dixie', 'Auburn', 'Talledaga', and more recently 'Chief' and 'Frontier' have been released. Is certified seed of these cultivars being used?

The western seed grower or the seed trade or both have subverted the name Dixie, and one finds Dixie type of reseeding crimson clover on the southern market. Here again, the name Dixie is being used as a gimmick or sales pitch. The usually dry summers in Oregon prevent the germination of common crimson seed so it volunteers in the fall, but it is not Dixie crimson clover. In addition, it contains seed of a mustard which is a serious weed in many Southern States.

Cooperatives and many quasi-State agencies that are supposed to furnish the best seed possible are selling such seed to their unsuspecting members because it is cheaper seed, and they think they have to compete with the hardware store dispenser of seed. Is any action being taken to discourage this movement of seed? Who should assume this responsibility?

Researchers have done an excellent job in breeding blue lupine. It can now be disease resistant, sweet tasting, and tolerant to winter freezes. Within the last two years, an extension service published a list of recommended varieties for fall planting, and 'Frost' was not included. Should extension agronomists permit this to occur? I have only listed a few of the glaring examples of what is happening in the southeastern area of the United States. I am sure there are many more examples similar to these.

The climate of the Southeastern States is not favorable for producing and harvesting high seed yields, particularly over a span of several years. Spring droughts or excessive periods of rain may reduce flowering and pollination and reduce the effectiveness of chemical treatments for the control of destructive insects, diseases, and weeds. Seed production in the region is mostly a byproduct of the farming enterprise. Farms lack appropriate machinery and low yields or seed crop failures are common. Last, but not least, is the farmer's lack of seed production knowledge and skills. His operations are geared to the production of cultivated crops.

The question is, where can seed of forage crops be produced most economically? The Western States have an ideal climate for seed production. In most locations a large percentage of the daylight hours are bright and sunny, with relatively low humidity. Irrigation supplies the water necessary for excellent plant growth. These factors promote flowering and favor the pollination necessary for seed-setting and harvesting. High yields are the general rule. The western seed grower is a specialized farmer who is cognizant of the requirements for insect control and the need for furnishing pollinating insects for most legume species. The small bulk and high unit value make transportation costs a small fraction of the total cost when seed is moved from the West to the East. The stage is set for the main production of seed in the West for consumption in the East, however, it is not that easy.

Development of Certification

Early Work

I would like to change directions slightly now and discuss some history. In the early 1920's, we found by comparative trials that common Oregon red clover seed was not adapted to conditions of the Eastern States.[2] However, this unadapted seed was being shipped east and sold to eastern farmers. Later, this was proved to be true with unadapted white clover and alfalfa shipped from California.

The first attempt to produce seed in the East was with the Tennessee anthracnose-resistant red clover. In the middle 1920's, several bushels of seed of this variety, bred by the late Professors Essary and Bain of the Tennessee Experiment Station, were sent to Oregon by the late Dr. A. J. Pieters of the Bureau of Plant Industry. The late George Hyslop, then of the Oregon Experiment Station, made arrangements for a trial planting for seed production. The seed furnished by Tennessee was of poor quality and contaminated with buckhorn and dodder. The western grower would not plant it because the noxious weed seed could not be removed, and he was not assured of an eastern market.

The idea of producing an eastern-adapted variety in the West was so new that the proposed procedure raised many legitimate questions. For how many generations could a forage variety be grown under western conditions before genetic changes affected its adaptation to eastern conditions? After all, common Oregon red clover has originated in the East. While this trial was an abortive attempt to change the production of common Oregon red clover into the production of a variety adapted to eastern conditions, it did stimulate an experiment to determine the number of generations for which an eastern-bred variety of red clover could grow under western conditions without undergoing significant changes in its adaptation.

In cooperation with the Kentucky, Oregon, and Tennessee Experiment Stations, we planned an experiment in which six generations of Tennessee anthracnose-resistant red clover would be grown at Corvallis, Oreg., and each year each generation would be tested at Arlington, Va.; Lexington, Ky.; and Knoxville, Tenn., using as a check Tennessee anthracnose-resistant seed grown continually in Tennessee. Those participating in this work were E. W. Fergus of the Kentucky Experiment Station, the late H. A. Schoth, U. S. Department of Agriculture (USDA), Oregon, and Harry Ogden from Tennessee; and Pieters and myself of the USDA. Odgen handled the maintenance of the seed of the anthracnose-resistant variety in Tennessee. H. W. Johnson of the USDA and Laurence Henson of the Kentucky Experiment Station examined the plants for anthracnose infection.

There were three flaws in the experiment. First, the plantings in Oregon had to be made at the Experiment Station in small plots just large enough to obtain sufficient seed for testing purposes. Second, the small seed plots maximized contamination by bees that carried pollen among plots holding different generations, even though each plot was isolated as far as possible from other generations and from common red clover. Dormant hard seed represented another potential source of contamination. Recent research has indicated that seed produced in the seedling year may cause changes or shifts in adaptation.

2/ Pieters, A. J., and Hollowell, E. A. 1928. Red clover. U. S. Dep. Agric. Leafl., 8pp.

Large cages could have been used, but funds for their construction and maintenance were not available at that time. The results of the experiment were never published in their entirety because of the possible shortcomings described above.

However, results of the first three generations of the test were published,[3] and they showed the beginning of a significant loss in adaptation after three generations of production under western Oregon conditions. Soon after the experiment was started, the Idaho Agricultural Experiment Station at Aberdeen cooperated in growing the generations under a different environment. The results were essentially the same.

In 1934, we started the production of 'Cumberland' and 'Midland' red clover varieties with a limitation of three generations when grown outside their region of adaptation. 'Kenland' replaced 'Cumberland', and 'Lakeland' and 'Dollard' have replaced 'Midland'. These in turn are being replaced by superior varieties as research progresses. It was difficult for me to accept the results of the apparent rapid genetic shifts after three generations of seed multiplication outside the region of adaptation.

Modern Certification

The International Crop Improvement Association, now the Association of Official Seed Certifying Agencies consisting of State and Canadian crop improvement associations, has developed standards, regulations, and procedures for the production and protection of germplasm of new varieties. This is called the certification of seed or, if vegetationally reproduced, certification of root stocks. As new research adds information that protects germplasm of superior varieties, the regulations and procedures are changed accordingly. I understand that this is being done for the red clover standards, as there seems to be a breakdown in adaptation between seed produced the year of seeding and the second-year seed crop. The new regulations will prohibit the harvesting of a seed crop during the year of seeding.

The use of certified seed of any variety, particularly when the seed has been grown outside its region of adaptation, is the only sure way of insuring to farmers in your States the benefits of plant breeding. Certified seed will cost more, but it is worth the extra cost. Some commercial seed firms that have good plant-breeding and production programs claim that their name gives as much assurance to consuming farmers as certified seed. This may or may not be true, depending on individual circumstances. Demand, scarcity, or abundance of seed of forage-crop varieties might change the accepted philosophy. Seed companies can certify their varieties under the same procedures available to State and Federal agencies. In fact, the certification of varieties developed by private companies might give those companies a greater measure of protection and public acceptance.

Most States have a state seed association which by common consent could have one company handle the contacts and the movement of seed stocks, and assemble and prorate certified seed production and distribution back to wholesalers who participated in the increase of the variety. This has proved to be

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3/ Beard, D. F., and Hollowell, E. A. 1952. The effect on performance when seed of forage crop varieties is grown under different environmental conditions. Proc. 6th Int. Grassld. Congr. 1: 860-866.

a satisfactory procedure in the increase of certified 'Chesapea ' red clover.

The State crop improvement association, the extension agronomist, and the plant breeder should be members of the decision-making or policy committee. This would not distrub the wholesaler-retailer relationship and would simplify the seed-producing procedures in the Western States. It would also protect the characteristics of the variety during all stages of certified seed increase.

Heat and Seeding

A new intriguing development which has recently been reported may help to solve the problem of undesirable genetic shifts in varieties produced outside their region of adaptation. Gibson and Chen[4/] report that self-incompatible clones of white clover become self-compatible or self-fertile when the temperature is increased from the range of 15° to 20° C to 25° to 30° C. This led to a very interesting speculation that under field conditions, high temperatures may increase selfing and loss of vigor for that specific seed generation. Experiments should be planned to test this hypothesis.

For many years I have been interested in temperature's effects on plant development and functions. Many years ago when I took a chemistry course, I was impressed by van't Hoff's rule which says that the rate of chemical reaction approximately doubles with a 10-degree rise in temperature. While there may be other factors connected with pollen tube growth and fertilization, I believe that high temperatures stimulate pollen tube growth enough to overcome many of the inhibiting factors found in some self-incompatible plants. The role of temperature in determining self-incompatibility and self-compatibility in *Trifolium* spp. has been explored by many workers. Townsend has presented an excellent review on the subject.[5/] I believe that additional research on temperature interactions and their relationship to interspecific and even intergeneric hybridization and seed production will be most exciting and rewarding.

During my annual migration from Florida to my home in Maryland, I stop at Clemson University in Clemson, S. C. to see Pryce Gibson and discuss his research. Here is a very interesing observation from an experiment. Self-incompatible clones, heavily loaded with seed and protected from tripping and wind movement, were growing in temperature-controlled cabinets at 35° C. This temperature of approximately 95° F, or above, is not uncommon during the summer months when white clover is blooming in fields.

I have often wondered why 'Ladino' white clover seed from the Josephine Ladino Seed Growers Association at Grants Pass, Oreg. nearly always gave slightly more production under eastern growing conditions than seed from the Sacramento Valley of California. Were we getting more selfing and inbreeding depression in the California seed? Also, I have wondered about the phylogeny of the *Trifolium* genus, the large number of its species, and its apparent center of origin in the Mediterranean region. What role did high temperatures play in the large array of species?

4/ Gibson, P. B., and Chen, Chi-Chang. 1973. Success in hybridizing and selfing *Trifolium repens* at different temperatures. Crop Sci. 13(6): 728-730.

5/ Townsend, C. E. 1971. Advances in the study of incompatibility. *In* J. Heslop-Harrison (ed.), Pollen: Development and Physiology, pp. 281-309. Buttersworth, London.

Responsibilities of Plant Breeders and Seed Handlers

Before naming and releasing a cultivar, plant breeders must provide for seed increase that will remain true to cultivar characteristics. Nothing kills a cultivar more quickly than giving it publicity when seed or a seed supply is more than a year away.

First, you should use the good seed producers in your State, but recognize that your environmental conditions may be unfavorable for profitable yields of seed. You may have to increase seed in the West to grow sufficient seed to supply the demands of consuming farmers. Of course, I think you should use certified seed.

I do not favor the sole assignment of seed stocks of a cultivar to a single seed company. I believe this to be discriminatory in giving exclusive marketing privileges and price-fixing to a single company. I question the legality of this practice.

Too many seed companies buy and sell seed as a commodity rather than as a genetic entity. Too many seed handlers buy solely on price, and some of these organizations claim to supply their patrons with the best quality seed of the best varieties available. I am a patron of one of these organizations and was not able to buy certified seed of Kentucky 31 or the Kenwell.

We need a seed trade interested in the western seed production of varieties adapted to our envirnoment and our specific needs. We need to produce and use as much homegrown seed of adapted varieties as can be commercially grown under our environment. We need a seed trade, including brokers or retailers, that will advise consumers of the potential deficiencies of seed labeled non-certified Louisiana S-1 white clover and 'Dixie' type of reseeding crimson clover.

The extension agronomist and the plant breeder must spend the time necessary to sell superior varieties to the consuming farmer. They must create a demand through all lines of communication--the press, the radio, and television. Some may say that this is extension's prerogative and responsibility. This may be true, providing that extension accepts its responsibility, but I do not think that this is being adequately done. The extension agronomist should meet with the seed trade and farm groups and see that there are continual demonstrations. After all, effective education is repetition.

Most extension agronomists working with grassland crops have been trained in management and nutrition and other cultural practices. Only one state has an extension plant breeder. Farmers of that state have a greater appreciation of the value of varietal adaptation than in any other state that I know of. A shining example is the approximately 11 million acres of 'Coastal' bermudagrass. Glenn Burton has sold and continues to sell 'Coastal' bermuda. I would hazard a guess that if he had not done this, the acreage would only be in the thousands. I think that extension agronomists should join with the plant breeder in selling adapted varieties.

The first step in pasture and forage programs is the use of seed of adapted cultivars, true to cultivars name. How many times do you see pasture and forage improvement programs outlined where no emphasis is placed on the use of certified seed of the recommended cultivars? I think this emphasis should be of primary importance in such programs. After the plant breeder produces a new variety, he or she and the extension agronomist must continually sell and protect it. Otherwise, the plant breeder's work may be in vain.

I have heard that administrative officials of two experiment stations have

stated that they are not employing additional plant breeders and that plant breeding should be done by private industry. The plant breeder would then become nothing more than a tester to police cultivar performance. I vehemently disagree with this idea.

I have more recently heard that some administrative officials of a few experiment stations and extension services have prohibited their personnel from making varietal recommendations. In place of recommendations, agronomists must merely present yield data, leaving the interpretation to the seedsmen and their dealers, letting them decide which seeds to stock and sell. I disagree with this practice for two reasons. First, it gives seed dealers the last word in deciding what to sell to farmers. Second, it deprives the extension agronomist of that close contact with farmers needed in the development of successful programs.

KENTUCKY'S BEEF INDUSTRY

By the Kentucky Extension Service

Animal agriculture allows the conversion of soil and climatic resources into useful products, resulting in new wealth. The relationships among plants, animals, and the soil offer many challenges to scientists specializing in these fields. Those of us associated with animal agriculture in Kentucky know that our State has great potential for increasing the income of farmers and contributing to the total food supply.

The business of converting forage to marketable products is already big in Kentucky in terms of volume and dollars. This is borne out in table 1 which shows the meat animals and dairy products marketed in Kentucky in 1972 and the cash receipts from the sales. Table 2 gives the changes in Kentucky's cattle from 1972 to 1973.

TABLE 1.--Forage-consuming animals and their dairy products and the cash receipts from sale of these animals, Kentucky, 1972[1/]

(Thousands)

Meat animals	Animals	Receipts
Cattle and calves------------------	1,380	$312,778
Hogs-------------------------------	2,020	109,356
Sheep and lambs--------------------	72	1,688
Milk and dairy products------------	---	145,000
Total----------------------------	3,472	$568,822

1/ Includes receipts from sales of farm-slaughtered meat.

TABLE 2.--Changes in Kentucky's cattle population from 1972 to 1973

Division of cattle	Thousands of animals in 1972	Thousands of animals in 1973	Percentage change from 1972-1973
Beef cows that have calved----------------	1,109	1,176	106
Milk cows that have claved----------------	326	324	99
For beef cow replacement, 500 pounds plus-	240	249	104
For milk cow replacement, 500 pounds plus-	91	91	100
Other Heifers, 500 pounds plus------------	71	71	100
Steers 500 pounds and over----------------	244	239	98
Bulls 500 pounds and over-----------------	55	59	107
Heifers, steers and bulls under 500 pounds	780	824	106
Total, all cattle	2,916	3,033	104

FORAGE DEMONSTRATIONS IN MISSISSIPPI

By Hiram D. Palmertree and J. W. (Bill) McKie [1/]

SUMMARY

Several high-intensity grazing demonstrations are in progress in Mississippi. Records are being kept in an attempt to teach cattle producers that by applying the research and demonstration information now available, the Extension Service personnel can show them how to produce enough forage on an acre of pasture land to feed one animal unit per acre. During the last 2 years, returns to land, labor, and capital have ranged from a low of $53 per acre to a high of $110 per acre, with an overall average of about $67 per acre. Fertilizer costs have averaged about $27.00 per acre, and beef production per acre has averaged about 390 pounds. Several tours and field days have been held on these farms, and the idea and techniques have been accepted by many producers and the majority of our fellow agricultural workers.

INTRODUCTION

The State of Mississippi has approximately 5 million acres of permanent pasture and several million additional acres of pastured woodland, while beef cattle of breeding age number 2 million. It has been estimated that there are an equivalent of about 3 acres of improved pasture for each beef cow in Mississippi. Statistics show that the average weaning weight of calves is 357 pounds, and a 75-percent calf crop has been assumed. This means that the average beef production in Mississippi is 89 pounds per acre.

With these statistics in mind and increased land costs facing cattle producers, increased beef production per acre has become a necessity. The most rapid increase in beef production per acre can come through reducing the acreage used per cow. To obtain ideas for ways to reduce the acreage per cow, the authors made several visits to the neighboring states of Louisiana and Texas to visit intensive management forage demonstrations already in progress. After reviewing the progress of the program and studying their techniques, a series of "cow-per-acre" demonstrations were initiated in Mississippi.

Initiation and Implementation

Three demonstrations were begun in 1971. There are now 14 cow-per-acre demonstrations being supervised by the Mississippi Cooperative Extension Service. In these demonstrations, area agronomy specialists assume the major

1/ Agronomist, Mississippi State University, Mississippi State 39762, and area agronomy specialist, Research and Extension Center, Poplarville, Miss. 39470, respectively, Mississippi Cooperative Extension Service.

role in assisting the local county agents and producers. In all cases, the demonstration is the producer's; that is, he has the final decision as to the management. The farmer does agree to follow as closely as possible the recommendations of the county agent and the agronomy specialist. The county agent agrees to supervise closely the application of all practices and keep accurate records. Extension Service personnel offer only suggestions and advice. The area specialist attempts to visit each demonstration and review the progress at intervals of approximately 3 weeks. All cooperators are encouraged to continue the demonstrations for at least 3 years.

The purpose of all demonstrations is to produce yearly all the forage needed by a cow and her calf for that year. The ultimate goal is to teach the producer rather than to show good demonstration results, but these are usually simultaneous.

The first step in establishing a demonstration is to accept the pasture and herd management program already in effect and apply to it the best techniques as we presently know them. A soil sample is taken for nutrient needs. In most cases, between 50 and 75 percent of the permanent summer grass (bahiagrass, common bermudagrass, or 'Coastal' bermudagrass) is overseeded with ryegrass in the fall. Some producers also use wheat sodseeded into the permanent sod. Some demonstrations include annual and perennial legumes. The fertilization rates are based on individual pasture needs, but most pastures do receive about 66 pounds actual nitrogen per acre four times per year, usually in April, June, October, and February. Sometimes an additional application of nitrogen is made in August if moisture is adequate.

Weeds are controlled with herbicides, thus reducing the clipping costs. Some pastures are clipped if growth becomes irregular.

No demonstration has fewer than three pastures and some have four, all using rotational grazing. At present the largest demonstration is 260 acres, and the smallest is 28 acres. Excess summer and winter forage not grazed is clipped and stored as hay.

Evaluation

From a forage standpoint, the only records kept are number of cow grazing days per acre, the out-of-pocket costs per acre, and the amount and value of hay harvested. Then, as the hay is fed, it is charged back to the wintering costs of the cow. Several records on the animals are kept. Calving date, weaning weight, and percentage of calf crop are recorded. Bull costs, veterinary supplies, and wintering costs are also charged against each animal unit. All results are reported as returns to land, labor, and capital per acre.

Results

Results from all demonstrations cannot be reported at this time because many are less than 1 year old. However, to give an example of the success of the program during the first 2 years, results of two demonstrations were selected, and summaries of the results of these two are presented in tables 1 and 2.

TABLE 1.--Forage demonstration with Wiley Ainsworth, Magee, Miss., using coastal bermudagrass on three pastures on 50 acres in 1971-1972. Demonstration stocked on March 28, 1972, with 50 cows, 2 bulls, and 45 calves (calves' average weight--200 lb)

Cost or income	Number	Weight	Costs/income
Income:			
Cattle sold:			
Calves	24	10,700	$4,789.82
Culled calves	3	820	417.00
Bales of hay harvested and sold	1,875	--	1,125.00
On hand:			
Heifers retained	10	--	1,750.00
Calves on hand	11	--	1,540.00
Total income and on hand			$9,621.82
Expenses:			
Wintering costs (October 1 to April 1, 1972)			$2,500.00
Feed purchases			264.00
Fertilizer and lime			1,124.90
Herbicides (2, 4-D; 3 applications)			150.00
Veterinary expense			125.00
Bull expense (@ $5/cow)			250.00
Total expenses			$4,413.90
Return to land, labor, and capital			$5,207.92
Return to land, labor, and capital per acre			$ 104.16

TABLE 2.--Forage demonstration with Leroy Smith, Brookhaven, Miss., using bahiagrass on three pastures on 35 acres in 1971-1972. Demonstration stocked on April 14, 1972, with 30 cows, 1 bull, and 23 calves (6 born in April; 1 died at birth)

Cost or income	Number	Weight	Costs/income
Income:			
Calves sold--------------------	29	11,592	$5,588.30
Bales of hay harvested and sold (@ 65¢/bale)-------------	50	--	32.50
Total income---			$5,620.80
Expenses:			
Estimated wintering costs (November 1 to April 14, 1972)---------------------------------			$1,500.00
Feed purchases, including creep feed---			207.00
Clipping and dragging--			80.00
Veterinary expense---			50.00
Bull expense (@ $5/cow)--			150.00
Fertilizer and lime expense--------------------------------------			835.00
Total expenses---			$2,822.20
Return to land, labor, and capital--------------------------------			$2,798.60
Return to land, labor, and capital per acre----------------------			$ 79.96

You will note that the wintering costs for 1971-72 were estimated to be $50 per cow. These estimates were used because all our demonstrations are run on an October to October year. This was selected because the fall is usually the marketing season for calves. The $50 estimated wintering cost was actually more than real amount, proven by accurate records kept on the demonstrations during 1972-73. Even with the severe winter, the wintering costs average only about $40 per cow. Therefore, it is safe to assume that the returns for 1972 were actually more per acre than the results show since the assumed wintering cost was more than real costs.

One additional interesting statistic is that on all demonstrations, the calving percentage has increased, and the calving date has been moved back earlier into the spring. One demonstration showed that the overall calving date was 21 days earlier than for the previous year, before the demonstration was initiated.

Problem Areas

Even with several successes, there have also been some problems. Initially, getting the agents and farmers to completely trust the idea is a major obstacle. The success of our demonstrations can be attributed to a few progressive county

agents who wanted the opportunity to participate in the program. The first three months were the most critical. This problem has been solved by frequent visits by extension personell and regular phone conversations with the producer. Another major problem was getting the producer to accept recommendations when adverse conditions such as drought prevailed. However, in all cases thus far in our demonstration program, cooperators completely endorsed the idea and techniques after the first year.

INTENSIVE GRAZING DEMONSTRATIONS

By W. E. Monroe [1]

Demonstrations in Louisiana

Over 4 million acres of land is devoted to forage production in Louisana. Less than a million head of breeding-age beef cattle and approximately 130,000 head of dairy animals utilize this forage. However, research work has shown that each acre of reasonably well-drained land is capable of producing adequate forage to carry a cow and her calf on a year-round basis at a profitable comparable to most row crops in the state if a good fertility and management program is followed.

Dairymen are doing a superior job in forage production and utilization in comparison to beef cattlemen. We of the Extension Service decided that all efforts should be made to get the Louisana beef cattlemen to do a better job of forage production and utilization. It was decided that the best approach would be set up a few intensive-grazing demonstrations. Since the first demonstration, which turned out to be of questionable success, was established in 1966, much has been learned about conducting a demonstration. The most important lesson was that a successful demonstration requires much planning from the start and careful supervision during its entirety.

We now conduct demonstrations under the basic framework given below.

Planning

(1) Demonstrations are set up only where there is a need and a genuine interest.

(2) All decisions are made by a previously arranged committee. The committee is as broadly based as possible and includes the demonstrators, extension and research personnel, and industry representation.

(3) If the deomnstration is to be financially sponsored by industry, the sponsors know what is expected of them and what will be done during the demonstration.

(4) The demonstrator is carefully selected and is made aware of what will be furnished him and what he is to furnish in return.

Implementation

(1) Soil samples are taken as a benchmark and for fertilizer recommendations.

(2) The forage program is built around the cattle needs, taking calving dates into consideration.

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(3) The demonstration area is divided into a least three parts with shade and water in each area.

(4) Grazing is started when there is something to graze, but forage is not allowed to accumulate.

(5) Cattle are tested for pregnancy and weighed when put into the demonstration.

Operations

(1) Proper utilization of the forage is of utmost importance is the demonstration is to be successful. A preconceived grazing schedule cannot be set up. The grazing rotation requires close supervision to rotate the animals use the forage produced as effectively as possible.

(2) Hay is made for winter-use each time the grass gets beyond the stage in which cows can convert it into milk.

(3) Weeds are controlled with herbicides only when necessary.

(4) The phosphate and potash needed, as determined by a soil test, is applied in the fall. Nitrogen is used during the growing season as necessary, its application being decided upon by the committee.

(5) Ryegrass is overseeded on the sod in the fall. Cows are concentrated in one area and given hay if necessary until the other pastures are ready to be grazed.

(6) Calves are weighed when weaned to determine the salable gain per acre.

(7) Pastures are grazed with one cow and her calf per acre. If forage becomes a limiting factor, fertilizer is used in excess of what is indicated by a soil test as being needed.

(8) Field days are held as often as practical for farmers in the area.

(9) The entire committee meets to discuss the demonstration at least twice a year, to pool information and inventory what each member has learned as a result of the demonstration.

Evaluation

Profit, as the most important factor, will ultimately determine the success of the demonstration. Therefore, the following items are considered in the evaluation.

(1) Careful records of all expenses.

(2) Participation and reaction of farmers ar field days.

(3) The demonstrators' reaction concerning the acceptance of the demonstration.

(4) Pasture improvement made in the area.

(5) Sponsors' reaction to results obtained.

A final warning concerning demonstrations is not to become oversold on the idea and establish more demonstrations than can be closely supervised. To be worthwhile, the projects require much time and attention.

FORAGE COUNCIL OF NORTH CAROLINA

By Sam H. Dobson [1/]

The forage and Grassland Committee of the North Carolina Cattlemen's Association is affiliated with the American Forage and Grassland Council. This affiliation resulted from recommendations of leading cattlemen who felt that since the cattlemen themselves were already organized and quite active in the forage area, a separate organization should not be set up. The Forage Committee has its own constitution and by-laws and is an official committee of the Cattlemen's Association.

There are about 75 members of the committee. Each of the 40 county Cattlemen's Association selects one member, and the farmers conducting forage and beef on-farm tests are all members. The Dean of Agriculture and the Director of Extension of North Carolina State University, Raleigh, each choose four members. The Forage Research and Extension Specialists at North Carolina State University are ex-officio members, the Seed, Fertilizer, and Farm Machinery Associations appoint a member, and the Commissioner of Agriculture of the State of North Carolina selects a member. The president and vice-president of the committee must be actively engaged in producing cattle. The Forage Extension Specialist is automatically secretary of the committee.

When one considers the fact that there are over 2,000 dues-paying members of the Cattlemen's Association in North Carolina, plus a 10¢ per head check-off fee at the sale barn, it is obvious that this association is a representative and influential group with which to be associated. Not only is it a good forum of interested farmers, but it provides financial backing for the forage program.

1/ North Carolina State University, Raleigh 27607.

COUNTY FORAGE COUNCILS IN OKLAHOMA

By L. M. Rommann 1/

The current work of organizing County Forage Councils is entirely in eastern Oklahoma. There are five Area Extension Agronomists located in western Oklahoma who are conducting pasture and forage educational programs in their respective areas.

The first County Forage Council was organized in northeastern Oklahoma in 1971. One of these cooperators had a rather typical operation of 340 acres, primarily bermudagrass under a low-fertility program. He was previously barely able to support 80 cows on this farm. His present operation includes tall fescue in solid stands, fescue-bermuda mixtures, and bermudagrass under a moderate fertility program. He is presently doubling the size of his herd, with further expansion possible. Total utilization of the forage produced is now a problem. He is selling part of his hay production, which he has never been able to do before.

Another cattleman in the same county was on a total native grass program. He is still using native grass for summer grazing, but he is rapidly establishing and using tall fescue for winter grazing. He will be able to expand his herd to the size he wants without converting much of his native grass to improved warm-season grasses. The potential exists for more expansion of the herd.

Another demonstration cooperator has a stocker-calf operation on tall fescue. This was a successful operation before he became a cooperator, but his fertility program was not well-balanced. Forage production has increased with a balanced fertility program.

The results of these County Forage Councils efforts are noticeable, judging from the attendance at tours and the number of questions coming to the County Extension Director about improving pastures. Members of the committee feel the results are better than they had expected.

Currently, there are 5 active forage councils with 10 more councils close to organization. Some of these demonstration programs will be organized through local cattlemen's association who also realize the need for improved, profitable forage production.

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THE TALL FESCUE BREEDING PROGRAM AT THE UNIVERSITY OF KENTUCKY

By R. C. Buckner [1/]

History of the Kentucky 31 Variety

In 1931, E. N. Fergus of the Agronomy Department of the University of Kentucky, Lexington was invited to judge a sorghum show at Frenchburg, KY. While there, he was taken to the farm of William Suiter to identify a new type of pasture grass that had been growing and providing valuable forage on Suiter's farm for approximately 40 years. Seed was obtained from Suiter, and the grass was evaluated on several of the Kentucky Agricultural Experiment Station Experimental Soils Fields and on farms in Kentucky by Fergus and other Agronomy Department personnel. The grass was officially released in 1942 as the ' Kentucky 31' variety of tall fescue.

During this evaluation period, the grass was discovered to have many attributes of a good pasture grass. It is widely adapted and grows well on the many and varied soil types of the state. It is a deep-rooted, long-lived perennial that is essentially a bunch grass, though it has short underground stems, and thick stands produce an even sod if kept mowed or grazed. The roots of tall fescue are tough and coarse, contributing to a good sod that will hold livestock and provide valuable pasture during extended wet and rainy periods when it would be impossible to graze other crops.

Although tall fescue is widely adapted, it grows best in a transition zone that separates the northern and southern regions of the United States. Most cool and warm-season grasses are not well adapted to this zone. Tall fescue is widely used in this zone between the latitudes of Indianapolis, Ind., and Macon, Ga., and the meridian of western Missouri and the eastern edge of the Piedmont area.

Generally, pure stands of tall fescue support a longer grazing period, higher stocking rate, and higher gain per hectare than pure stands of orchard-grass and grass-legume mixtures. Nitrogen fertilizer slightly depressed average daily gains, nearly doubled carrying capacities of the tall fescue pastures, and greatly increased live weight increase per hectare.

The many valuable uses of tall fescue for forage, turf, and conservation purposes resulted in a rapid increase in 'Kentucky 31' plantings after its release in 1942. Within the boundaries of the transition zone, approximately 7,200,000 hectare of tall fescue are grown in pure and mixed stands. Hectarages in Kentucky, Missouri, and Tennessee are large. Most of the hectarage of tall fescue in the transition zone is 'Kentucky 31', and this variety has become the

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predominant cool-season grass in Kentucky. Seed production has increased from a few hundred kilograms in 1942 to 32,413,181 kilograms in 1971.

Forage quality

A high-quality forage has been defined as one with the greatest possible concentration of utilizable nutrients in a form highly acceptable to animals. Criteria used to determine forage quality include the percentages of crude protein, crude fiber, soluble carbohydrates, and mineral elements and the digestibility, acceptability, and intake of the forage by livestock. The forage quality of tall fescue is equal to that of other cool-season pasture grasses. However, many investigators have studied animal performance on tall fescue pastures in pure seedings and in fescue-legume mixtures in comparison with that on other grasses, and the results are extremely variable. Average daily gains of cattle grazing fescue are superior in some tests and inferior in others. Gains on tall fescue during the 3 to 4 months of midsummer were reported to be nil by workers at the Southern Indiana Forage Farm; however, in a Rowan County, N.C., test, animal performance on fescue was superior to that on bermudagrass.

Breeding for Improved Palatability

One criticism of tall fescue, almost from the time of its release, is that it is somewhat unpalatable to livestock, especially during the summer and early fall. Thus, workers assumed that poor palatability during the summer period resulted in low intake, which resulted, in turn, in the erratic performance of livestock grazing this grass during this period. Therefore, a breeding program was initiated in 1950 to develop a variety of tall fescue more acceptable to livestock, especially during the summer.

The 'Kenwell' tall fescue variety, developed cooperatively by the Kentucky Agricultural Experiment Station and the Agricultural Research Service, U. S. Department of Agriculture, was released in 1965. 'Kenwell' is characterized by improved palatability when grazed free-choice by livestock, improved disease resistance, and better maintenance of color during drought.

'Kenwell' and 'Kentucky 31' were compared for animal performance on the Kentucky Agricultural Experiment Station Farm and on private farms in western Kentucky during 1962 to 1964. Little difference in animal performance was observed between the two varieties at any of the test locations. This would indicate that the two varieties are essentially the same nutritionally. Consequently, preferential grazing of 'Kenwell' by livestock during the summer did not solve the problem of erratic performance of cattle on tall fescue during this period.

Toxicity problems

Tall fescue compares favorably with other grasses in *in vitro* digestibility. However, it is not consumed as readily, and intake by cattle, except during the fall, is more variable than with other grasses. Therefore, although digestibility is an effective measure of forage quality in many cool-season grasses, it does not seem so for tall fescue. Apparently, undesirable constituents are responsible for the erratic quality of tall fescue and subsequent poor performance by cattle grazing it during late spring and summer.

Although many alkaloid-like substances have been detected in extracts of

tall fescue, perloline is the major alkaloid. Its content is related to season, genotype, and the amount of applied nitrogen. Levels are highest during July and August in fescue heavily fertilized with nitrogen. The erratic perfomance of animals during summer parallels the accumulation of alkaloids in tall fescue during the growing season. Perloline inhibits in vitro ruminal cellulose digestion, fatty acid production, and growth of ruminal cellulolytic bacteria. It is hypothesized that perloline, therefore, inhibits the rate of digestion in the rumen and, consequently, that the rate of passage through the animal decreases. These factors decrease intake and thereby decrease energy and nutrient availability to the animal.

Lolium-Festuca hybridization

Intergeneric and interspecific hybridization of the *Lolium* and *Festuca* species is being used in an effort to transfer the forage qualities of annual and perennial ryegrass and of giant fescue to tall fescue while maintaining the excellent agronomic qualities of tall fescue.

The ryegrass (2*n*=14 chromosomes) x tall fescue (2*n*=42 chromosomes) *F*1 hybrids all have 28 chromosomes and are male-sterile. Fertility has been achieved by backcrossing to the parents. Several annual ryegrass x tall fescue amphiploids (2*n*=56 chromosomes) have been obtained by treatment with colchicine; however, because of meiotic instability, fertility has not been achieved in these amphiploids.

As a consequence of apparent non reduction of egg cells in the *F*1 chromosome hybrids, several 56-chromosome amphiploids have been obtained by pollinating the *F*1 hybrids with the 56-chromosome annual ryegrass x tall fescue amphiploids. Eleven clones obtained from these materials in the fourth generation of selection had foliar characteristics that appeared to be intermediate between the annual ryegrass and tall fescue parents. The eleven clones had 2*n*=42 chromosomes and were quite stable meiotically and completely fertile.

'Kenhy', a new tall fescue variety with much potential, was developed by polycrossing the 11 selected clones and forming a synthetic variety. 'Kenhy', when tested over a 3-year period at Lexington, Ky., had 11 percent higher dry matter yields, was 5 percent higher in *in vitro* digestibility, had 14 percent less lignin, and was grazed free-choice 47 percent more by cattle than was 'Kentucky 31'. 'Kenhy' had essentially the same perloline levels as 'Kentucky 31'. Preliminary testing in 21 other states indicates that 'Kenhy' is apparently as widely adapted as 'Kentucky 31'.

Animal performance data comparing 'Kenhy' and 'Kentucky 31' tall fescue are being obtained by the Kentucky, Missouri, Oklahoma, and Virginia Agricultural Experiment Stations and by the Middle Tennessee State University, Murfreesboro, Tenn.

Breeding for low perloline

Because perloline content may indirectly influence forage quality and finally affect the perfomance of ruminants grazing tall fescue, a study has been made to determine the extent of intergeneric and intrageneric differences in perloline content of *Festuca* and *Lolium* spp. and the heritability of perloline in ryegrass-tall fescue hybrids previously selected for improved quality.

Lolium spp. had less perloline than *Festuca* spp.; *L. multiflorum* had the smallest amount of perloline and *F. elatior* the largest. Although highly significant genotypic-environmental interactions were obtained for perloline

quantity for a 3-year period, broad-sense heritability estimates varied from 0.57 to 0.80 among polycross progenies of thee groups of genetic materials. Correlation coefficients of association between parents and progenies were positive and highly significant. The data suggest that genetic control of perloline may depend on relatively few genes and that progress can be made toward the development of *Lolium*-*Festuca* populations that are either high or low in perloline content.

CYTOLOGY OF TALL FESCUE AND HYBRID DERIVATIVES

By G. T. Webster [1/]

INTRODUCTION

Tall fescue, Festuca arundiancea Schreb., is generally considered to be a hexaploid, $2N=42$, with a basic genome complement of seven chromosomes. It is strongly diploidized with regular formation of 21 bivalents, although it has occasional deviations. During microsporogenesis, the deviant cells show primarily univalents with infrequent multivalents. In the species, there is a complete range in self-fertility from highly self-sterile to highly self-fertile plants. The nature of the self-incompatibility has not been determined. Ecotypes in Europe and North Africa have been reported with $2N=56$ and 70.

Ryegrass x Tall Fescue Hybrids

The male-sterile hybrids between annual and perennial ryegrass x tall fescue showed varying degrees of chromosome pairing and variations in numbers of micronuclei in the pollen quartets. We are routinely using the latter variation as a measure of meiotic regularity.

Amphiploid progenies selected for vigor, type, and good seed set have been polycrossed for successive generations. In each generation, representatives of nearly the entire range from 42 to 56 chromosomes have been recovered but in no case did we find plants approaching regularity in meiosis, even after seven generations.

Backcrossing amphiploids to tall fescue or to the F_1 plants results in a rapid return to meiotically stable tall-fescue types. Likewise, backcrosses to ryegrass quickly revert to ryegrass types.

Plants with chromosome numbers which can be accounted for only as a consequence of non reduction are found regularly in these hybrid derivatives.

Attempts to recover stable euploid progenies with chromosome numbers other than 14 and 42 have been almost totally unsuccessful. Only one, a $2N=56$ with a reasonably low micronuclei count of 1.5, has been found. Selfing or crossing with other 56-chromosome derivatives has not yielded any additional $2N=56$ types.

Tall Fescue x Giant Fescue Hybrids

Giant fescue, Festuca gigantea, also appears to be a $2N=42$ hexaploid with regular formation of 21 bivalents. Plants which we have studied appear to be somewhat more regular meiotically than tall fescue although this observation is

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based on a very limited sample.

The five $2\underline{N}=42$ F_1 plants obtained were all highly male-sterile. Meiotic irregularities were nearly always expressed as univalents, ranging from plant means of 10.1 to 13.7 per cell with an overall mean of 11.8. This would suggest that tall fescue and giant fescue may have two genomes in common.

Forty-one progenies from two colchicine-treated F_1 hybrids had chromosome numbers ranging from 80 to 84. Bivalent formation was exceptionally high in those cells in which the chromosomes were spread well enough that associations could be determined. The few irregularities which were observed were predominantly univalents with very few multivalents. Unfortunately, practically none of these progenies survived the winter of 1972.

However, progenies of four $2\underline{N}=63$ plants derived from outcrossing ryegrass x tall fescue amphiploids did survive. Ninety-six progenies from the $2\underline{N}=63$ plants ranged in chromosome number from 46 to 74. We have reason to believe that this material may yield several desirable stable types.

PHYSIOLOGY AND ANIMAL NUTRITION

By J. A. Boling, R. C. Buckner, and L. P. Bush [1/]

INTRODUCTION

Tall fescue, Festuca arundinacea Schreb, is a perennial, cool-season grass which has become predominant on livestock farms throughout the Southeastern United States. The high yields of dry matter, the carrying capacity, and the adaptability of tall fescue are among the factors which have contributed to the dramatic increase in acreage during the last 20 years. Even though tall fescue is prevalent on most farms, there are many questions remaining to be answered concerning its management, nutritional value, and the observed variability in performance by grazing cattle, especially during the summer months. The utility of any forage depends on the quantity and quality of nutrients which it supplies to the grazing animal for required metabolic processes, such as maintenance, growth, reproduction, and lactation.

Ruminant animals are endowed with the capacity to utilize forages in large quantities through the action of the rumen bacteria and protozoa. It is through this system that they can be maintained, grow, and reproduce on feedstuffs that are not in competition with those consumed by man.

Nutritive Value of Fescue vs. Other Forages

Several studies have compared the performance of cattle grazing tall fescue with those grazing other grasses from spring to early fall. Jacobson et al. (9)[2/] compared the gains of yearling dairy animals on pure seedings of orchardgrass, Kentucky bluegrass and 'Kentucky 31' tall fescue. Orchardgrass and bluegrass produced similar and the most consistent gains. The gains of cattle grazing 'Kentucky 31' were more variable, but in 1961 the gains were equal to that of orchardgrass and bluegrass. In the 1964-1966 trials, the gains of the cattle grazing 'Kentucky 31' were significantly greater than the gains of cattle grazing orchardgrass.

Mott et al. (11) reported the seasonal gain patterns of steers grazing tall fescue pasture. Low and erratic gains were observed during the months of May, June, and July, and weight loss was observed during the month of August. The overall average daily gain for the 4-year study was 227 grams. This depression in gain during the summer months was overcome by feeding corn grain at the rate of 1 kilogram per 100 kilograms liveweight daily. This resulted in an increase in average daily gain to 576 grams.

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2/ Underlined numbers in parentheses refer to items in "Literature Cited" at the end of this paper.

In a study presently being conducted at the University of Kentucky (G. M. Hill, unpublished data), we are comparing the performance of Angus calves from birth until weaning in which the calves and their dams are grazing either fescue-ladino or bluegrass-ladino clover pasture (table 1). Each group of 15 cows and calves is assigned to 30 acres of pasture. The 30 acres are subdivided into four 7 1/2-acre plots to practice rotational grazing. Excess forage is harvested as hay. The average birth date of the calves has been around April 1, in a 75-day calving season. The average daily gains for the calves in the fescue group have averaged 0.12 kilograms less than for those grazing the bluegrass-ladino clover pasture.

TABLE 1.--Growth rates of spring-born calves on fescue-ladino clover or bluegrass-ladino clover pasture from birth until weaning1/

Year2/	Average daily gain (kilograms)	
	Fescue	Bluegrass
1970	0.80	0.88
1971	0.85	1.00
1972	0.88	1.00
Average	0.84	0.96

1/ Average weaning age of calves was 214 days.
2/ There was 15 calves evaluated each year.

In some recent studies at the University of Kentucky by M. H. Wallace et al. (unpublished data), lambs were used to determine the digestibility of 'Kenwell', 'Kentucky 31' and orchardgrass hays harvested at three stages of maturity. The overall apparent digestibility coefficients for organic matter were 63.4, 64.0, and 63.6 percent for the three grasses, respectively. The apparent digestibility of crude protein was essentially the same for 'Kenwell' (57.7 percent) and 'Kentucky 31' (57.9 percent) while orchardgrass had a slightly higher (61.6 percent) crude protein digestibility.

When the three grasses were compared on the basis of stage of maturity (table 2), the apparent digestibility of organic matter average about 66 percent at stages I and II for 'Kenwell', 'Kentucky 31', and orchardgrass. However, in stage III, apparent digestibility of organic matter averaged about 58 percent, a decrease of 7 to 9 percent for all grasses. Crude protein digestibility was also similar for stages I and II for the three grasses. In stage III, crude protein digestibility was decreased to 49 percent for 'Kenwell' and 52 percent for 'Kentucky 31', but was reduced to only 57 percent for orchardgrass. Since the time interval between the early-leaf and early-bloom stages was only about 2 weeks, these data point to the significant changes which can occur in utilization of forage by the animal in a very short period of time.

Buckner and Bush (unpublished data) have used the dry-matter disappearance technique of Donefer et al. (6) to determine the estimated quality of tall fescue, ryegrass-tall fescue hybrids, bluegrass, and orchardgrass sampled at different times during the year. The different grasses were sampled in April, August, and November. The nutritive value index (NVI) was highest at the April sampling for all grasses. The November sampling was intermediate and the August sampling lowest in NVI. Using this technique, tall fescue and its

hybrid derivatives compared very excellently to bluegrass and orchardgrass. These data point to the seasonal influence on nutrient digestibility not only for fescue, but also for other cool-season grasses.

TABLE 2.--Effect of stage of maturity of grass on apparent digestibility of organic matter and crude protein, measured as percent digestibility

Grass	Stage of maturity 1/ I	II	III
	Percent apparent digestibility of organic matter		
'Kenwell'------------	66.2 (5/24)	66.7 (5/31)	57.2 (6/7)
'Kentucky 31'--------	67.8 (5/22)	66.1 (5/31)	58.0 (6/7)
Orchardgrass---------	66.5 (5/15)	65.7 (5/24)	58.6 (6/2)
	Percent apparent digestibility of crude protein		
'Kenwell'------------	62.7	61.2	49.0
'Kentucky 31'--------	61.4	60.3	52.1
Orchardgrass---------	63.8	63.6	57.4

1/ Dates of cut are in parentheses.

Crude Protein and Amino Acid Content of Fescue

The crude protein content and relative quantities of some of the essential amino acids in tall fescue and ryegrass-tall fescue lines are presented in table 3 (4). A large proportion of the protein ingested by ruminants is deaminated in the rumen to form ammonia. Some of the ammonia is utilized to synthesize rumen microbial protein, and the remaining ammonia is absorbed through the rumen wall into the bloodstream. Protein quality, especially for young, growing, yearling cattle, is presently being viewed with increasing and renewed interest. The balance of amino acids absorbed from the lower gut of the ruminant influences the utilization of the amino acids by the animal tissues. The amino acids reaching the lower gut for absorption are derived from proteins which escape ruminal deamination and the proteins of rumen bacteria and protozoa.

The data in table 3 show the variability in crude protein content and the variation in quantity, as well as quality (or amino-acid balance), among lines. 'Kentucky 31' was slightly lower in crude protein than the other grasses, and the AT amphiploid (the 56-chromosome, F1 progeny from the annual ryegrass-tall fescue cross) was highest. The 'Kenhy', the (at) t backcross (the 28-chromosome, F1 progeny from annual ryegrass x tall fescue backcrossed with tall fescue), and 'Kenwell' were very similar in crude protein content. For comparison, the six amino acids shown here have been set at 1.00 for 'Kentucky 31'. The 'Kenhy' line was higher in arginine, histidine, leucine, lysine, and threonine and lower in methionine then 'Kentucky 31'. The ryegrass-tall fescue (at) t backcross was lower in the amino acids determined than any of the other lines. The AT amphiploid was lower in lysine and methionine, and

'Kenwell' was lower in histidine, methionine, and threonine than was 'Kentucky 31'.

TABLE 3.--Protein content and relative quatities of essential amino acids in tall fescue and ryegrass-tall fescue lines[1/]

	Grass				
	(at)AT[2/]	(at)t[3/]	AT	'Kenwell'	'Kentucky 31'
Protein(%)	19.1	19.9	23.2	20.9	17.9
Arginine	1.39	.96	1.08	1.10	1.00
Histidine	1.18	.75	1.07	.88	1.00
Leucine	1.16	.91	1.27	1.20	1.00
Lysine	1.19	.77	.97	1.29	1.00
Methionine	.93	.84	.90	.87	1.00
Threonine	1.27	.91	1.16	.95	1.00

1/ From Bush, L. P., and Buckner, R. C. 1973. Tall fescue toxicity. In Arthur G. Matches (ed.), Anti-quality Components of Forages. Crop Sci. Soc. Amer. Spec. Publ. No. 4, pp. 99-112, and unpublished data.

2/ Cross between the 28-chromosome, F1 progeny from annual ryegrass x tall fescue (at) and the 56-chromosome, F1 progeny from annual ryegrass x tall fescue (AT).

3/ Backcross between at and tall fescue (t).

Perloline Content

Another factor which has been shown to influence the in vitro utilization of fescue is the alkaloid perloline, which has received a great deal of study by our group at the Universtiy of Kentucky. Perloline is one of the major alkaloids present in tall fescue, and it is closely related structurally to perlolidine, which is also present in tall fescue. There are several other alkaloids which have been isolated from fescue, such as loline (also called festucine) and several loline derivatives.

The seasonal pattern of accumulation of perloline in tall fescue was reported at the University of Kentucky by Gentry (7). Perloline concentration in the plant usually peaks in late July or early August. The magnitude and positioning of the peak can be influenced by both climatic and management practices. Interest was further stimulated in the possible relationship between perloline and animal performance when it was observed that summer gains of steers on tall fescue were sometimes depressed during the months that perloline concentrations peaked.

Perloline level is influenced by the level of nitrogen fertilization, which is common practice in management of grasses to increase yields (7). Perloline concentration across all nitrogen levels peaked at the early August sampling. Gentry et al. (8) showed that perloline accumulation was more responsive to nitrogen fertilization than with phosphorus or potassium fertilization in 'Alta', 'Kentucky 31', and 'Kenwell' tall fescue. In these studies, 'Alta' was lowest and 'Kenwell' was highest in perloline.

Bush and Buckner (4) observed that tall fescue seedlings grown in the

greenhouse increased in perloline content as the level of nitrogen in the nutrient solution was increased. At 60 days, the 1N level had a perloline concentration of approximately 700 microgram per gram, and at the 10N level the concentration of perloline was increased to 3,000 micrograms per gram.

Bush et al. (5) reported that perloline inhibited the in vitro digestion of cellulose using solka floc (purified wood cellulose) and tall fescue as substrates. Perloline concentrations used in this and subsequent studies were calculated, using the data of Gentry (7) on accumulation in tall fescue to, estimate ruminal concentrations which might occur under grazing conditions. This study and subsequent in vitro artificial rumen studies were conducted similar to the techniques described by Baumgardt et al. (1).

Further studies (4) indicated that substrate influenced the response of the in vitro system to added perloline. Solka floc is a readily available source of cellulose for rumen microorganisms. The cellulose in plant materials is combined with and can be partially protected from digestion by several substances, such as ligin and proteinaceous compounds. The endogenous perloline concentration of the plant material also appears to have an effect on digestion. This is particularly true with line 68-13, a ryegrass tall fescue hybrid backcrossed to tall fescue that has been selected for high perloline content and contains 11 milligrams per gram of material. The digestion of this grass was inhibited to a greater extent than was solka floc.

Bush et al. (3) reported on studies designed to determine some of the possible causes for the observed inhibition of cellulose digestion. Volatile fatty acid production in vitro was inhibited at perloline concentrations greater than 1.2 x 10 -4 molar when measurements were made after 24 hours of incubation. As perloline concentration increased, the proportion of propionic acid decreased from 26 to 20 percent, and the proportion of butyric acid increased from 10 to 15 percent when the control tubes were compared with the high perloline levels. Isovaleric and valeric acids also tended to be higher as the perloline concentration increased.

A further study by Bush et al. (3) was conducted to determine the influence of perloline on the growth of isolated rumen cellulolytic bacteria. Bacteriodes succinogenes, Butyrivibrio fibrisolvens, Ruminococcus albus, and Ruminococcus flavefaciens were supplied to us in pure culture by M. P. Bryant, University of Illinois, Urbana. The bacertia were grown under anaerobic conditions using prereduced media, with perloline treatment added. The growth was measured as change in growth with respect to control tubes after 24 and 48 hours of incubation. The growth of Bacteriodes succinogenes was stimulated at the lowest concentration of perloline at both 24 and 48 hours of incubation. The growth of Ruminococcus albus and Ruminococcus flavefaciens was inhibited at both 24 and 48 hours of incubation with 10 -4 molar perloline. With the exception of Ruminococcus albus, bacterial growth was inhibited about 80 percent at 24 hours by 5 x 10 -4 molar perloline. The growth of all four bacteria were inhibited approximately 80 percent at 48 hours. These was no observable growth of the four bacteria at either 24 or 48 hours in tubes containing 10 -3 molar perloline. Protozoa were isolated from rumen fluid by the addition of 50 milliliters of 20% (weight per volume) glucose solution per liter of rumen fluid in a separatory funnel. After settling to the bottom of the funnel, the protozoa were removed and suspended in rumen fluid which had been filtered through Whatman No. 1 filter paper. They were incubated under conditions similar to in vitro rumen fermentation and samples withdrawn for counting over a 48-hour period. At the levels of 0 and 2.71 x 10 -4 molar perloline, no

apparent effect on viability of the protozoa was observed. At concentrations of 5.66 x 10 -4 molar perloline and greater, a graded effect was observed on rumen protozoal viability. At the highest level, 95 percent of the protozoa were dead in 7.5 hours.

Several ryegrass-tall fescue hybrids have been selected for perloline content (2). As examples (table 4), within the 'Kenhy' line, entry 39-27 had a concentration of 5,133 micrograms of perloline per gram of material and 78-5 had 396 micrograms per gram. Within the (at)t backcross (ryegrass-tall fescue backcrossed to tall fescue), entry 68-13 had a concentration of 11, 896 micrograms perloline per gram and 65-3 had 14 micrograms per gram. Leaf disks were prepared from these fresh materials and incubated in rumen fluid similar to the procedures of Monson et al. (10). Subjective evaluation of the leaf disks indicated less digestion of the grasses which were highest in perloline (Bush, unpublished data).

TABLE 4.--Perloline content of ryegrass-tall fescue hybrids, in microgram per gram[1/]

(at)AT Pedigree[2/]		(at)t Pedigree[3/]	
Entry	Perloline	Entry	Perloline
39-27	5133	68-13	11896
78-5	396	65-3	14

1/ Buckner, R. C., Bush, L. P., and Burrus, P. B. 1973. Variability and heritability of perloline in *Festuca* species, *Lolium* species, and *Lolium-Festuca* hybrids. Crop Sci. 13(6): 666-669.

2/ Cross between the 28-chromosome, F1 progeny from annual ryegrass x tall fescue (at) and the 56-chromosome, F1 progeny from annual ryegrass x tall fescue (AT).

3/ Backcross between at and tall fescue (t).

CONCLUSION

Several factors can interact to contribute to the poor performance sometimes observed in cattle grazing tall fescue. Variety, composition, stage of maturity, and palatibility of the grass and seasonal influences are among the major factors affecting utilization. Alkaloids, especially perloline, may play a significant role at certain times during the year. The inhibition of cellulose digestion by perloline may result in increased rumen fill and decreased rate of passage of undigested feed residues. This would result in decreased feed intake by the ruminant, thereby, reducing the intake of all nutrients. It is likely that perloline may inhibit the activity of enzymes related to cellulose digestion and inhibit or reduce synthesis of DNA by rumen microorganisms.

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APPROACHES TO THE PROBLEM OF FESCUE TOXICITY IN CATTLE

By H. L. Tookey, S. G. Yates, and M. D. Grove 1/

INTRODUCTION

The term fescue toxicity includes three rather distinct syndromes which may or may not be related to one another. The first syndrome is fescue foot, in which cattle develop rough hair coats, become lame, and develop gangrene of the extremities, particularly the rear hoofs. The second is a condition called summer syndrome, in which cattle become unthrifty and have elevated body temperatures and respiration rates. The third condition is fat necrosis, or lipomatosis, in which the abdominal fat of cattle contains necrotic patches. Fat necrosis has been associated with poultry litter fertilization of pastures in the southeastern piedmont plain.

Fescue Foot

This paper deals primarily with fescue foot. Nearly all results are work that the North Central Regional Research Center, Agricultural Research Service, U.S. Department of Agriculture, Peoria, Ill., has been associated with, and include cooptive work with Kentucky, Missouri, and Wisconsin Agricultural Experiment Stations.

Fescue foot has been a problem for many years in a region extending from Missouri eastward through Kentucky and in scattered areas farther east or farther south. The disease is believed noninfectious and occurs sporadically, but over widespread areas. In Missouri and Kentucky the disease appears typically in herds on winter pasture of tall fescue.

After cattle have been on fescue from 1 to several weeks, symptoms may appear. Of 100 cattle on a pasture in Missouri in 1967, 11 became lame. These animals were thin, were lame in the hindquarters, and had rough hair coats and arched backs (fig. 1). Usually, the earliest signs in the feet are swelling and a red line at the coronary band, followed by cracking of the skin at the junction of hoof and skin on the rear feet (fig. 2). As one animal who had these symptoms was led into a barn, the hoof from one digit simply fell off. Cattle affected so severely they can no longer walk often give birth to normal calves, indicating that abortion is not an expected part of the syndrome. Tail necrosis is a less dramatic sign, but it is often present. Of 57 cattle on another Missouri pasture in 1970, 7 were lame. All seven as well as 45 others, over 90 percent of the herd, had tail lesions (fig. 3).

If cattle are removed from toxic pasture before much damage is done, they may recover and show only a bobtail or abnormal hoof growth as permanent

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damage. The syndrome resembles ergotism, yet ergot sclerotia are consistently absent from pastures giving rise to fescue foot. Nor has selenium been implicated. The selenium content of several toxic forages ranged from 1 to 2 parts per million. Levels of sodium selenite as high as 30 parts per million did not cause symptoms resembling fescue foot.

Mycotoxins

The high incidence of fescue foot in winter and its will-o'-the-wisp nature, appearing in a pasture one season and not the next, led us to suspect that the cattle were being poisoned by a mold metabolite, a mycotoxin. Many outbreaks of fescue foot occur on pastures where rank growth of forage was allowed to accumulate and so provide dead or dying foliage full of mold growth. Cold weather might stimulate a mold to produce toxins, as was shown by Joffe (5).[2/] Another factor suggesting that molds are involved in fescue toxicity is the fact that infection of the grass with *Stemphylium*, *Rhizoctonia*, or *Helminthosporium* alters the kinds or amount of alkaloids produced by the grass (7).

Samples of toxic hay were extracted with ether and the extractives painted on a rabbit's dehaired back. Five of eleven extracts produced hemorrhagic lesions. Nontoxic, sterile fescue hay was enriched with glucose and peptone and inoculated with three molds isolated from toxic fescue forage. Extracts from these moldy hay cultures were tested orally in cattle at the Kentucky Agriculture Experiment Station. Extracts from two pounds of hay molded with *Fusarium tricinctum* killed two cattle quickly. A lower daily dose, from 0.4 pounds of hay, for 15 days produced no toxic symptoms. No toxic results were obtained from the *Epicoccum* or *Cladosporium* cultures.

Numerous samples of forage were collected in 1967 from a large toxic fescue pasture and from orchardgrass pastures nearby. These samples were examined for fungal flora. The usual, expected genera were present (table 1). Though fewer in number, the fungi from orchardgrass showed the same genera of fungi as did the fescue. A range of 4,000 to 20,000 propagules of *Fusarium* per gram of hay is common in Missouri fescue pastures. Mice were used as test animals to survey extracts from these fungal isolates for toxicity. Nearly half of the *Fusarium* isolates were lethal to mice. *Fusarium tricinctum*, one of the molds found earlier on fescue forage, was selected for further study.

TABLE 1.--Toxicity to mice of fungi from grass samples

Genus	Isolates from toxic fescue		Isolates from orchardgrass	
	Total	Toxic[1/]	Total	Toxic[1/]
Alternaria	18	5	3	0
Cladosporium	28	7	5	0
Epicoccum	28	3	3	0
Fusarium	29	18	5	3
Mucor	11	0	0	0
Other	32	3	2	1

1/ Toxic means that extracts from one-tenth culture plate killed at least 1 of 2 mice or made 2 of 2 noticeably sick within 4 days after intraperitoneal injection.

2/ Underlined numbers in parentheses refer to items in "General References" at the end of this paper.

F. tricinctum produces at least three toxins when grown at 15°C on Sabourauds agar. Two of these have been tested in cattle, a butenolide (fig. 4) and the trichothecene T-2 toxin (fig. 5). The butenolide was a previously unknown compound; it has also been reported from *F. equiseti*. Because isolation of the butenolide from mold cultures is difficult, a chemical synthesis was modified to enable us to make the compound in large enough quantities for cattle testing. T-2 toxin was isolated from culture extracts by extraction with ethyl acetate followed by chromatography on silica gel.

Testing of these two toxins in cattle was carried out during the winter in Madison, Wis. This was done in the winter because reduction in blood flow to the extemities in cold weather might enhance the clinical effects of the toxins. All animals were maintained on a nontoxic fescue ration. The toxins were given by daily intramuscular injections as shown in table 2.

TABLE 2.--Intramuscular administration of T-2 and butenolide mycotoxins to cattle maintained on nontoxic fescue

Compound	Daily dose (mg/kg)	Days dosed	Avg. weight change (%)	Other signs
T-2--------------------	0.1	65	-17	Hemorrhage.
Butenolide-------------	3.8	90	-20	Necrotic tail.
T-2 and butenolide---	.06 and .9	42	-16	None.
None-------------------	0.00	90	+ 1	None.

The animal receiving T-2 toxin had a bloody discharge from the nostrils on day 64 and died the following day. Clotting time taken antemortem was 6 to 7 times normal. Autopsy findings included ecchymotic hemorrhages of the epicardium and endocardium and of the small intestine, and a massive hemorhage into the large intestine. The general internal hemorrhages resembled those seen in cattle consuming moldy corn, rather than resembling fescue toxicity. Indeed, a recent report from the University of Wisconsin indicated the presence of T-2 toxin in a field sample of corn that was toxic to cattle (4).

The animal receiving the butenolide gradually developed a red tint at the tail tip. By day 54 the tip had darkened and a distinct white ring appeared about 4 centimeters from the tip (Fig. 6). By day 61 necrosis had all but separated the dead tip from the remainder of the tail (fig. 7). The animal had an arched back, but no hoof abnormalities could be found, either clinically or at autopsy. The animal receiving both toxins lost weight but showed no other signs; this result indicates little or no synergism between T-2 toxin and the butenolide.

A later experiment, also at Madison, Wis., was carried out in an unheated barn. Animals were given daily doses of the butenolide by ruminal fistula (table 3). Those experimental animals maintained on nontoxic fescue survived; those on timothy hay died. Thus, a fescue ration is not required for butenolide to exert its effect. In addition to tail lesions, these experimental animals all lost weight and showed tubular nephritis and hepatitis, but no hoof abnormalities were found.

Other cattle were given a culture of *F. tricinctum* grown on fescue hay (enriched with glucose and peptone) at the rate of 2.2 grams per kilogram of body weight each day for 70 days (table 4). The signs and lesions in these cattle were similar to those in animals given the butenolide. This similarity would lead one to postulate butenolide in the cultures. But there was no demonstrable butenolide in these *F. tricinctum* cultures. The toxic effects must therefore have been caused by a butenloide precursor or some related alternate metabolite.

TABLE 3.--Intraruminal administration of butenolide mycotoxin to cattle

Heifer	Ration	Daily dose (mg/kg)	Days dosed	Disposition
1--------	Timothy---------	22	19	Died
2--------	" ---------	22	35	"
3--------	" ---------	16	43	"
4--------	Fescue ---------	22	70	Destroyed
5--------	" ---------	22	69	"
6--------	" ---------	16	52	"
7-10--	Timothy or Fescue----	--	--	Controls

TABLE 4.--Intraruminal administration of Fusarium tricinctum cultures to cattle

Heifer	Ration	Daily dose (g/kg)	Days dosed	Weight change, 48 days (%)
11--------	Timothy--------	2.2	74	-3
12--------	" --------	2.2	74	+5
13--------	Fescue---------	2.2	70	-10
14--------	"	2.2	69	-19

Our investigations showed that *F. tricinctum* or the butenolide mycotoxin caused gangrene of the tail, but no hoof gangrene was observed. Comparable effects were found when the rumen acted on the toxins and when the rumen was bypassed.

Another group of workers at Mississippi State University has also been using the mycotoxin approach to the fescue problem. Preliminary findings reported last year at the Southern Forage Physiology and Ecology Work Group indicated that thiabendazol, a drug with fungicidal activity, might be of value in controlling fescue toxicity to cattle. Populations of *Aspergillus terreus* in rumen contents were associated with fescue toxicity in these preliminary findings (9).

Alkaloids

Alkaloids were investigated along with other components on the premise that, since alkaloids are usually biologically active, they may contribute to toxicity. The alkaloids of tall fescue are closely related to those of rye-grass. Fescue alkaloids (fig. 8) may be divided into three classes: perlo-line, loline and its relatives, and unknown alkaloids. The total alkaloid content of fescue forage rises during the summer months and then falls. Robbins and Wilkinson found total alkaloid content to be above 0.3 percent, particularly on well-fertilized summer pasture. These workers found that loline and its derivatives decreased weight gain and feed consumption of rats when the alkaloids were 0.2 percent of their diet (6). Thus, the loline group of alkaloids is suspect as a factor in poor animal performance in summer, though it probably is not the cause of foot gangrene. An alkaloid fraction rich in loline was given to cattle and was not toxic.

Perloline is perhaps the most abundant alkaloid in summer fescue. Its level rises sharply during July and August and may exceed 0.35 percent of forage dry weight. It has been shown by Bush et al. (1) that 9×10^{-5} M perloline inhibits cellulose digestion *in vitro*. Currently, work is underway at our laboratory to isolate enough perloline for animal trials at Kentucky Agriculture Experiment Station to show whether or not perloline can be blamed for poor animal performance.

Fractionation of Toxic Forage

The most direct approach to finding the cause of fescue toxicity is to systematically fractionate toxic forage and test the various fractions in the cow. The first experiments resulted in a concentrated extract and three subfractions (fig. 9), lipids, alkaloids, and aqueous residue. The concentrated extract produced fescue foot when given intraruminally. Of the subfractions, only the aqueous phases showed effects after 11 days' dosing and produced a purple tail. The alkaloid fraction was rich in loline but was nontoxic (table 5).

TABLE 5.--Cattle bioassay of fractions from toxic tall-fescue hay

Fraction from G 1-43 1/	Days	Pounds of hay processed to get daily dosage	Results
I	37	16	Characteristic signs of fescue foot.
II	10	17½	Early signs of gangrene in tail.
III	10	17½	Nontoxic.
IV	11	21	Surface temperature and purple discoloration of tail.
V	11	21	"
VI	11	21	"

1/ The strain of tall fescue from which the fraction comes.

Feeding trials in cattle were time consuming and required processing of 300 pounds of hay for each animal. Often this amount of hay was difficult to obtain. A search for a small animal bioassay that shows a correlation to fescue foot in cattle has been unsuccessful.

The development of an experimental pasture in Missouri which reliably produces toxic forage led to a recent renewal of the fractionation approach. Garner (2) follows a managment practice that includes fertilization twice each fall with 87 kilograms of nitrogen per hectare and has produced toxic forage each winter.

In order to keep hay requirements within reasonable limits, intraperitoneal injection was tried in the winter of 1971-72. This experiment overlapped the older experiments to be sure that bypassing the rumen would be successful. Ovendried hay was extracted with 80 percent ethanol. After defatting and filtration, the concentrated extract was given to two steers maintained on a dehydrated alfalfa ration. A daily dose of extract from less than 2 kilograms of hay for 14 days produced characteristic signs of fescue foot. Gangrene was produced in the tips of the tails much as in previous tests with mycotoxins. Foot lesions occurred in both animals (fig. 10), with the red line at the

coronary band that is characteristic of early stages of fescue foot.

We believe this experiment demonstrates that the rumen environment is not needed to convert a substance of either microbial or plant origin to the actual toxin causing fescue foot. Further fractionations of toxic hay are in progress to isolate the toxin.

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Fig. 1. Cow with fescue foot.

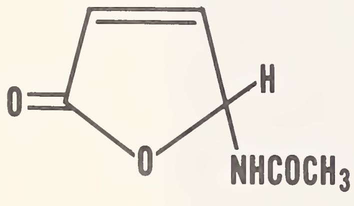
Fig. 2. Rear hoofs of cow in fig. 1.

Fig. 3. Tail lesion of heifer on fescue pasture. Other cattle on this pasture had purple discoloration of distal portion of the tail.

Fig. 4. Structure of the butenolide

Fig. 5. Structure of T-2 toxin.

4-Acetamido-4-hydroxy-2-butenoic Acid
γ-Lactone



T-2 Toxin

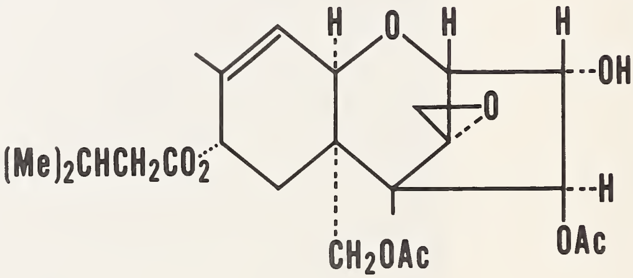


Fig. 6. Gangrenous tail of heifer receiving the butenolide.

Fig. 7. Final stage of tail gangrene in heifer receiving the butenolide.

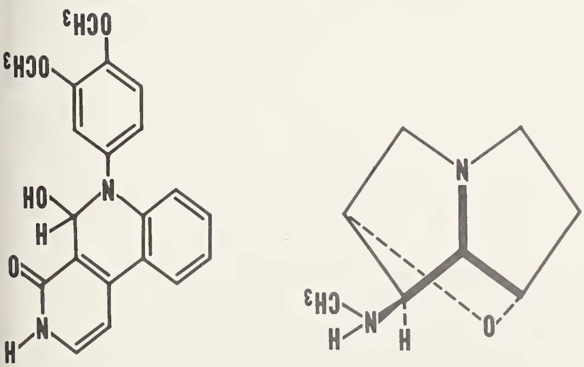


Fig. 8. Alkaloids of fescue loline (<u>left</u>) and perloline (<u>right</u>).

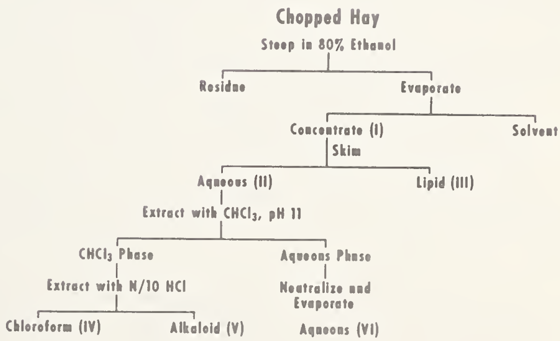


Fig. 9. Fractionation of toxic extract.

Figure 10. Rear hoof of animal receiving toxic extract intraperitoneally.

FORAGES IN KENTUCKY

By Warren C. Thompson [1/]

Present Production and Uses

Sixty-seven percent of the open cropland acreage in Kentucky is devoted to the production of forage crops, grown mainly for cattle feed. Pasture crops occupy 7.8 million acres; hay, 1.5 million acres; and grain silage, 0.2 million acres.

Cool-season perennial grasses predominate in pastures. Tall fescue is the leader at an estimated 6 million acres. Kentucky bluegrass is grown on 1.5 million acres. Orchardgrass and timothy together make up a total of about 300,000 acres. The leading pasture legumes are white clover (including 'Ladino'), red clover, annual lespedeza, and alfalfa.

During each of the past 3 years, 3.1 to 3.5 million tons of hay have been harvested. The volume is up one million tons since the mid-1960's. The top acreages hay crops are tall fescue and red clover. Well over two-thirds of the 1.5 million tons of these crops is harvested from fields that were renovated before seeding as a pasture crop. Because of the usual surplus feed in May and early June, these crops are harvested as hay and stored for use at crisis periods of need.

Alfalfa and alfalfa grass mixtures play a major role in supplying stored hay needs, especially for dairy herds. In spite of the alfalfa weevil, over 200,000 acres of alfalfa are harvested annually with average acre yields ranging from 3.1 to 3.5 tons. Straight grass hay is important to the livestock but it is usually carelessly made and is fed to the beef cow-calf herd. In recent years it has been used primarily for winter feed for the dry pregnant beef cow. Annual lespedeza as a reliable source of stored hay for winter feed is quickly losing its importance due to low, inconsistent yields.

The silage program is centered around corn. About 18 percent of the total corn acreage is made into silage. The average yields in 1972 were 14.5 tons per acre, with a range of 11.0 to 25.0 tons per acre. Hay silages are used primarily by dairy farmers as an effort to harvest the first crop of alfalfa and red clover, as insurance against rain damage. In recent years there has been considerable interest in double-cropping and using both corn and smallgrain for silage. This system is mostly confined to dairy farms where high stocking rates exist on rather small acreage.

During the past 15 years, there has been a considerable interest in upgrading forage production in volume and quality. The number of beef cows has increased over 100 percent in that period. Among the many reasons for this gain have been (1) the increased volume of better quality forage, especially in grazing crops; (2) the introduction of legumes into grasses, which has made possible better season-to-season distribution of feed to fill the animals'

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needs; (3) an effort by farmers to pick up income slack as tobacco came under fire; (4) the increased demand for beef and the ability of this area to respond to this demand with more cattle, as contrasted with severely limiting factors in some areas.

There are four areas of particular concern that serve as the limiting factors to the expansion of forage production and consumption in Kentucky.

Seasonal distribution of production. Since Kentucky is basically a cool-season-grass- and legume-producing area, and since the acceptance of warm-season perennials as well as summer annuals has been strongly resisted by farmers, there is a serious problem in obtaining high-quality, high-volume feed in mid-summer, especially when we rely on tall fescue and bluegrass renovation, introducing legumes into the grass sward in an effort to upgrade the quality and to screen out some of the problems associated with little growth in the summertime. Another factor that has helped tremendously with seasonal distribution has been the use of nitrogen in the late summer on straight grass, especially on fescue and bluegrass, for the production of stockpiled pasturage. The harvest of surplus grazing as hay for use in crisis periods has also made a real contribution. In recent years, alfalfa has returned to the scene but has often been planted on land having a greater slope than was usual in earlier years. As a result, much of the alfalfa production is limited in summertime yield due to droughts. In areas where droughts resulted in limited good recovery and yields are low, the July and August harvests are often grazed to help alleviate some of these problems.

Yield. Selecting species with higher yielding potential has become widely practiced in the past decade. The substitution of red clover for lespedeza, alfalfa for red clover, and corn silage for alfalfa on level land are selections that farmers are using at an increasing pace. Add to this a forage fertilizer program suited to the crops' needs and the soil's needs, applied at the proper times, and an easing of the strain on the limited manufacturing and distribution facilities, and the way to higher yields becomes clearer.

Utilization. Farmers are reviewing livestock programs to better utilize the feed they produce. When beef cattle were selling for 20¢ to 25¢ a pound, not much attention was given to calving seasons, type of cattle, marketing needs, stocking rates, etc. But today farmers are more concerned with calving seasons, bullpens, cattle types, and the growing period needed for cattle to reach maturity, always considering the best and most reliable source of high-quality forage. Dairy farmers are building the majority of their feed program around stored feed, silage, and hay, crops grown on level land. Other crops grown on sloped land supplement silage and hay. More and more farmers are also interested in total milk production from the total acreage as contrasted with yield per cow.

Economic perspectives. In Kentucky, as in most states, economic evaluation of forage are usually made in relation to row crops, regardless of slope, fertility, and other special factors. Since so much land here is suitable only for forage production, our emphasis is to they as much from forage areas as possible and to look at net income per acre instead of just efficiency of income. So much of the land is classified in Classes III through VII that very few alternatives exist other than forages.

Priorities in Forage Programs

During the past 15 years, there has been a very active program at the University of Kentucky and among the lay leadership throughout the state to solve major production and management problems. The most important step in accelerating the forage program was the organization of the Kentucky Forage and Grassland Council. The group was formed in 1960 and became affiliated with the American Forage and Grassland Council in 1962. This group of key farmers and agribusiness and professional leaders from throughout the state has helped to identify problems and priorities for forage work. Areas that have received the majority of attention are discussed below.

Grassland renovation. In 1959, 17,000 acres of grass were renovated. In 1972, for the fifth consecutive year, over 500,000 acres were renovated. This program was initiated through method-and-result demonstrations on an intensive scale at the county level, and is now accepted as a farm practice that is simple to perform and rewarding in response.

Forage fertilization. As in most states, forage fertilization has lagged behind row crop fertilization in Kentucky. Off-season distrivution to relieve the workload of the farmer and the market facilities of the manufacturer, plus higher prices for livestock and livestock products, have encouraged farmers to use more fertilizer and realize higher yields. Improvements in seasonal production patterns are likely. An estimated increase of 61 percent in farmers using fertilizer on forage crops in the past 10 years seems realistic. This program has been conducted primarily through leader- and agent- training programs.

Alfalfa production. More alfalfa will be seeded in 1973 than will be plowed, for the third time in 3 years. Even though the weevil is an increasing menace and labor shortages greatly hamper harvest, the crop acreage yield per acre will increase in 1973 over 1972. Add ot this the cost and projected supply of processed protein supplements, and a vast acreage increase of perhaps 50 percent is expected by 1975. This program has been conducted through mass media and demonstrations at the local level.

Silage. The production of silage has risen 300 percent since 1960. Most of this gain has been from corn. The emphasis has been on the dent-harvest, fine-chop, tight-pack, and fast-fill operations. Unpredicted gains have been made in small grain silage as well as in hay silages. The silage program has been conducted basically through mass publicity and leader training workshops.

Planned land use. An important concern has long been how to best use our limited level land for row crops and plentiful sloped land for forage production. Through a program that encourages planned land use, we hope to achieve maximum energy production to support animal needs, despite our lack of land suitable for row-crop production. Evaluation of this long-term program can be made at present only by noting our increasing forage and row-crop yields.

Feed and livestock have become recognized as the vasis for agricultural growth and expansion in Kentucky, and a program supporting them is of top priority in education and service agencies. Therefore, in-depth training, planning, and program development activity concerning the soil, plants, and livestock have become the nucleus of the agronomy and animal science work. This work is not confined to agencies, but reaches into all segments of professional recommendation programs throughout the state.

County forage and grassland councils have been formed in 46 Kentucky counties. The councils have the prime responsibility to help identify problems in feed production and use, establish priorities for work to be done,

and assist in the execution of programs to get large-scale adoption of new practices.

There have been radical changes in forage production and use in Kentucky in recent years. Yet when we look at our potential, we recognize that we have applied only about one-third of our present knowledge, and can increase cattle feed production at least twofold above present levels.

LIVESTOCK IN KENTUCKY

By Nelson Gay [1/]

Animal agriculture allows the conversion of natural resources such as soils and climate into useful products. Kentucky is particularly well-suited to producing forage, and the business of converting forage into saleable products is big. Those of us who are closely associated with animal agriculture in Kentucky know there is great potential, as yet unrealized.

Table 1 shows numbers and cash receipts from meat animals marketed in 1972. When receipts from milk and dairy products are added (table 2) a total of $568,822,000 is seen. This is almost 60 percent of total agricultural income. Forage-consuming cattle and calves are listed by class in table 3. These figures show beef cow numbers increasing, dairy cow numbers about constant, and more calves being kept in stocker or backgrounding operations.

TABLE 1.--Animal marketed in and cash receipts from meat-animal operations in Kentucky, 1972[1/] (Thousands)

Meat animals	Animals	Receipts
Cattle and calves------------------	1,380	$312,778
Hogs-------------------------------	2,020	109,356
Sheep and lambs--------------------	72	1,688
Total	4,472	$423,822

1/ Includes receipts from marketings and from sales of farm slaughtered meat.

TABLE 2.--Total receipts from forage-consuming animals in Kentucky in 1972

Source	Receipts (thousands)
Meat animals--	$432,822
Milk and dairy products	145,000
Total	$568,822

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TABLE 3.--Number of livestock in Kentucky by classes in 1972 and 1973
(Thousands)

Class of livestock	1972	1973
Beef cows that have calved	1,109	1,176
Milk cows that have calved	326	324
For beef cow replacement, 500 pounds and over	240	249
For milk cow replacement, 500 pounds and over	91	91
Other heifers, 500 pounds and over	71	71
Steers, 500 pounds and over	244	239
Bulls, 500 pounds and over	55	59
Heifers, steers, and bulls under 500 pounds	780	824
Total all cattle	2,916	3,033

Kentucky has 89,000 beef cattle farms, 27,000 dairy farms and 26,000 hog farms. These farms have over 3 million head of cattle, 1,352,000 hogs, and 72,000 sheep and lambs.

Beef cattle and their potential According to U. S. Department of Agriculture estimates for January 1, 1973, Kentucky ranked 10th nationally in beef cow numbers and 14th nationally in all cattle. Assuming that a potential for increased beef production exists in Kentucky, how does this relate to the situation nationally? Experts tell us that by 1980 a national cow herd of 46.3 million will be needed. This is a 24 percent increase over 1970 or about 9 million head of cows. The Southeast is expected to account for 2.65 million head of this increase. Kentuckians are expected to increase their cow numbers from 1.065 million to 1.624 million by 1980. This accounts for over 20 percent of the increase expected in the Southeast and for over 6 percent of the total increase nationally.

Soil, topography, and climatic conditions in Kentucky are such that increased beef production will likely occur as feeder calves and yearlings. Climatic conditions that favor forage production are not particularly favorable to cattle finishing. High levels of rainfall during winter and spring is a deterrent to concentration of cattle in large commercial feedlots. Modification of the environment with buildings and concrete to increase cattle performance, to lower labor inputs, and to better manage wastes will likely increase. Minimum tillage techniques will allow many operators to increase row-crop production to support backgrounding 100 to 300 head of calves. These yearling feeders will likely be sold to high-plains feedlots for finishing on high-energy rations.

Many operators are presently engaged in so-called wintering or stocker programs. These usually involve a wintering phase on hay or standing forage, limited grain, and protein supplement. Levels of gain are 0.5 to 1.5 lbs per day. A pasture phase follows during which gains of 1.0 to 1.5 pounds per day are expected. Ownership of cattle extends for approximately 10 months during which 300 pounds of gain are expected. Other operations consist of only a pasture phase which lasts for 120 to 180 days. In these programs, calves are purchased in the spring and sold in the fall when forage is no longer available.

Some of the characteristics of the beef cattle enterprise in Kentucky are worthy of consideration when attempting to evaluate beef-forage production relationships. Numbers per cow herd are small, usually with less than 20 head.

Many herds are maintained as sources of supplementary income by part-time operators. Combination of burley tobacco and beef cattle on the same farm is common. Requirements of these enterprises are such that this is practical. Burley is a low land, high labor input enterprise, while beef cattle require relatively low labor and high land input. Reasons given by farmers for having a beef enterprise include (1) utilization of otherwise unused land or roughage resources or both, (2) less labor with beef cattle than with alternative livestock enterprises, and (3) contribution to income (from a survey of beef production in Kentucky, Justus, 1973).

Typically, the management of cow herds has been loose. Calving seasons have been longer than desirable and not necessarily related to forage supply. Overfeeding or underfeeding of brood cows has been common. Bulls have run with the cow herd year-round. Grazing practice has been continuous, whole-boundary, or mob grazing.

Recently, prices for calves and yearlings have caused cowmen to give more consideration to their herds. Seasonal calving, pasture renovation, the use of superior bulls, crossbreeding, and other recommended practices appear to be on the upswing. Continued favorable prices will likely bring about more brush clearing, pasture improvement, fencing and a more rapid buildup of the cow herd.

Annual feed needs of a cow-calf unit are estimated at 5 tons of hay equivalent or 5,000 pounds of total digestible nutrients. These needs can be supplied by 2 acres of improved pasture. Estimates of the potential of land use and production reveal a capacity for increased numbers of cow herds and backgrounding operations. Much of the forage available for the cow-herd increase has resulted from a sharp decline in sheep and a gradual decrease in dairy cows. Continued expansion will have to involve increased forage production or more efficient utilization of existing acreage or perhaps both.

RED CLOVER BREEDING

By M. K. Anderson and N. L. Taylor [1/]

INTRODUCTION

Red clover, Trifolium pratense L., is a widely grown legume in Kentucky. Grown mostly in combination with grasses such as tall fescue, it is the most important legume hay crop in Kentucky. It is used mostly for hay and pasture and fits well into crop rotation systems, and has the added value of being useful in soil improvement. Because of the importance of this legume, we are engaged in a red clover breeding program at the University of Kentucky in Lexington. We will attempt to give you an overview of the goals, objectives, and progress of our program.

Our major objective, related to all aspects of our program is to develop more persistent, high-yielding varieties of red clover. Two, possibly three, different approaches are being used in the development of these superior varieties. Conventional methods of forage-crop breeding, such as mass selection and polycross progeny testing, were used to develop 'Kenstar', a soon-to-be-released variety. It is expected that 'Kenstar' will replace 'Kenland', an open-pollinated red clover variety released cooperatively by the Kentucky Agricultural Experiment Station and U. S. Department of Agriculture in 1947.

'Kenstar' is a 10-clone synthetic variety selected for greater persistence under Kentucky conditions than is available in 'Kenland' and other varieties. Stands of 'Kenstar' under optimum management conditions have lived for 3 to 4 years, counting the year of seeding as the first year. 'Kenstar' is similar to to 'Kenland' in general appearance, resistance to southern anthracnose and powdery mildew, and area of adaptation. The 10 clones are maintained vegetatively to reconstitute the variety as seed is needed. Breeder, foundation, and certified seed are being increased in Kentucky.

In addition, we are trying to generate improved synthetics by backcrossing improved disease resistance into the 10 I_0 parent clones of 'Kenstar'. We are trying to incorporate greater powdery mildew resistance and bean yellow mosaic virus resistance, working cooperatively with Steve Diachun and Lawrence Henson, in anticipation that these synthetics will show greater persistence. Incorporation of mildew resistance has proceeded through five backcrosses, using the I_0 parent as the recurrent parent, intercrossing with a selection of clones showing homozygous resistance by mass-screening the progenies, and polycross increase of seed from the I_0 selected mildew-resistant clones. Incorporation of bean yellow mosaic virus resistance is in the fifth backcross stage at present, again using the I_0 parent as the recurrent parent and intercrossing with selection; eventually, increase of polycross seed will follow. Some difficulty is being encountered in infecting plants for screening purposes from continued

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backcrossing for bean yellow mosaic virus resistance. It appears that some of the 10 parent clones whose polycross progenies compose 'Kenstar' may already have a type of resistance which inhibits infection and thus the screening process.

In addition, we are continually looking at our synthetics in regard to class and seed-source tests. We have several experiments, in cooperation with C. S. Garrison of the U. S. Department of Agriculture, which should provide a better understanding of the relationship between persistence and class of seed and location of increase of seed.

Several European reports have indicated tetraploid red clover types have increased disease resistance, persistence, or dry-matter yield. We are in the process of producing a tetraploid synthetic comparable to 'Kenstar' so that exact comparisons can be made of genotypes at the diploid and tetraploid levels.

Double-Cross Hybrid Red Clover Varieties

We are also deeply involved in developing double-cross hybrid red clover varieties. Genetic control of crossing to produce a true double-cross hybrid is accomplished by the one-locus, gametophytic incompatibility system. In essence, the procedure for producing a double-cross hybrid involves (1) selfing I_0 clones to obtain I_1 progenies; (2) selecting agronomically desirable I_1's which are homozygous for _S_-genotypes; (3) increasing desirable I_1's by vegetative or seed increase schemes; (4) producing two single crosses from four selected and increased I_1's; and (5) blending single-cross seed for sowing to produce double-cross hybrid seed.

Red clover plants, although normally self-incompatible, may be inbred by pseudo-self-compatibility (PSC). Very limited amounts of selfed seeds can be produced under normal field conditions, or greater amounts can be obtained by exposing excised or attached heads to elevated temperatures of 40° C. The I_1 generation will segregate into either normal (1:2:1) or unusual ratios of heterozygous and homozygous _S_-allele genotypes, but in either case sufficient homozygotes which are necessary for genetic control of crossing will be produced for use in the double-cross hybrid. We have found that we can accurately classify _S_-genotype homozygotes under caged conditions in the field which alleviates the laborious hand crossing necessary when _S_-genotype classifications are made in the greenhouse. This is accomplished by small vegetative increases of each I_1 plant produced. Each of the I_1 progeny from a particular I_0 clone is then caged at pollination time. I_1 rows showing relatively high amounts of seed set will be homozygous for _S_-genotype, and I_1 rows showing relatively low amounts of seed set are heterozygous for _S_-genotype. This method has proved to be effective for classifying _S_-genotypes for I_1 progenies from 8 of the 10 I_0 parent clones.

Selfing will also reduce the vigor of the I_1 progenies, the amount varying with the particular I_0 parent clone. In most cases, the vigor is restored when the I_1 lines are crossed to produce single crosses. Investigations using selected inbred clones in a diallel crossing system are underway to determine if we can recover lines high in specific combining ability. These lines would be used to produce a double-cross hybrid.

There are alternatives for the maintenance and increase of the inbred lines used to produce a double-cross hybrid. These alternatives involve seed or vegetative maintenance and increase or combinations of both. In order to exclusively use seed maintenance and increase of inbred lines, it is necessary

to have a small but heritable degree of PSC and stability of S-alleles during inbreeding. Any mutation or change in S-specificity upon inbreeding will result in a loss of controlled matings, and true hybrids will not be produced. We have found that PSC declines upon inbreeding. We have also verified all I_2 clones for any changes in S-specificity and found that a change or mutation in S-genotype occurred in one I_2 progeny. If several generations of seed increase of inbreds were required, changes in S-specificity as we found could cause appreciable contamination. Thus, it appears that some combination of of both seed and vegetative increases holds the most promise.

We have produced a number of double-cross hybrids to date. Most of these were produced to ascertain the effectiveness of genetic control of crossing by the gametophytic incompatibility system. Most of these double crosses were similar to improved synthetics such as 'Kenstar' in performance. However, we felt that one double cross did hold some potential and in 1972 we produced, cooperatively with C. S. Garrison, about 4 kilograms of double-cross hybrid seed at Prosser, Wash. In the spring of 1973, this hybrid was sent to 17 states comprising 26 locations for testing.

Interspecific Hybridization

In addition to these two specific breeding programs, we are also attempting interspecific hybridization with several perennial *Trifolium* species as a method of introducing desirable characteristics. The only successful interspecific hybrids with red clover to date have been with the annual species of *Trifolium*, *diffusum* and *pallidum*. We have attempted to cross *T. medium* with red clover and used high-temperature treatments (40°C) on the female parent in conjunction with the attempted interspecific hybridization. We found the high temperature treatment of no benefit, at least in crosses of *T. medium* with red clover. It is hoped that with an increased understanding of interspecific incompatibility barriers, we can eventually obtain characteristics such as increased longevity from some of the perennial species of *Trifolium*.

Approximately 175 of the 250 to 300 *Trifolium* species are maintained at this station. We have obtained chemotaxonomic data as well as somatic chromosome numbers on many of these species. Our chemotaxonomic data on species' relationships as a predictive value of successful interspecific hybridizations looks very promising to date.

BREEDING FOR RUST RESISTANCE IN TALL FESCUE

By Charles D. Berry [1/]

Tall fescue is the basis for much of the winter grazing for brood cow herds in Alabama. Our best estimate is that an excess of 900,000 acres of tall fescue are presently being utilized in Alabama alone, and of course this same story can be retold for most of the southeastern states. Beyond this, tall fescue is planted in much of the United States.

Since tall fescue is a major source of winter forage in many of the southern States, a severe outbreak of crown rust on this species could be devastating to our forage program. This is especially true since much of our acreage is based on a single variety, 'Kentucky 31', a monoculture similar to that preceding the Southern corn-leaf blight outbreak of 1970 in the United States.

As early as 1967, severe crown rust was observed on the variety 'Goar' in Alabama. This prompted the initiation of a project for the identification of rust resistance in 'Goar'. However, before I got this project off the ground, severe rust infections were observed in 1970 on isolated fields of 'Kentucky 31'. In 1971, extension rust infections were observed on 'Kentucky 31' throughout Alabama and on some acreage in Missouri, Tennessee, Kentucky, and North Carolina. Thus, the project for identification of rust resistance was extended to 'Kentucky 31'.

The crown rust pathogen of tall fescue was identified by both R. T. Gudauskas, Auburn University, Auburn, Ala., and G. B. Cummings, Purdue University, Lafayette, Ind., as *Puccinia coronata Corda.* var. *coronata*. The pathogen must infect the alternate host, *Rhamnus* spp., to complete the sexual reproduction cycle, but the pathogen can probably overwinter in the South as urediospores, providing a ready source of inoculum for continual reinfection. In addition to the identification of the pathogen, inoculum collected from naturally infected 'Goar' and 'Kentucky 31' plants have been identified as separate races of *Puccinia coronata* Corda. var. *coronata*. The 'Kentucky 31' race parasitized both 'Goar' and 'Kentucky 31' varieties with equal facility, while the 'Goar' race was pathogenic almost exclusively on 'Goar' seedlings. The presence of at least these two races indicates the potential for development of more strongly virulent races in the future.

Using the successful development of rust-resistant 'Magnolia' annual ryegrass, *Lolium multiflorum* Lam., by Peter Bennett as inspiration. R. T. Gudauskas and I[2/] launched a program to determine requirements for production of artificial epiohytotics of these races, at will, for screening purposes. Our objectives were to develop a procedure for evaluation of large numbers of tall fescue seedlings for crown rust-resistance in greenhouse culture, and one which provided reasonable assurance that all plants were exposed to equivalent inoculum load to minimize the escape of any seedlings.

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2/ Berry, Charles D., and Gudauskas, Robert T. 1972. Susceptibility of tall fescue *Festuca arundinacea* Screb., to crown rust. Crop Sci. 12(1): 101-102.

Establishing a standardized screening procedure involved determining the storage conditions necessary for maintenance of a bulk supply of inoculum, a spore diluent to serve as an inoculum carrier, an inoculum concentration which yielded consistent levels of infection, and the optimum temperature for infection and sporulation

Using data from the various tests conducted to elucidate these factors and reported in Crop Science, a screening procedure has been developed which provide a relatively easy means of evaluating a large number of plants. Six-Week-old seedlings grown in individual peat pots, held in metal flats, are pre-moistened with .05 percent solution of a surfactant, using a readily available inexpensive hand sprayer. Seelings are then inoculated with a 1:40 talc dilution of urediospores by dusting inoculum through two layers of cheesecloth onto exposed leaf surfaces (133 milligrams of spores per flat of seedling). The flats, six per inoculation, are then held overnight in a plastic-enclosed mist chamber which is equipped with a humidifier that operates continuously. Inoculated seedlings are then incubated in a cool greenhouse in a temperature range of 21°C to 26°C for 12 days. Plants are subsequently rated individually for rust incidence using the infection classification of Murphy[3/] and by estimating percentage of leaf surface rusted on a 10-10 scale where 0=no rust and 10=91-100 percent. Leaf symptoms vary from complete coverage with large pustules, to a few very small pustules, to complete freedom from pustule development. All apparently resistant plants are inoculated a second time to verify the results.

Using this screening technique, 8,400 'Goar' seedlings have been evaluated and 173 (2 percent) apparently resistant plants have been identified. These plants are being selfed to produce seed for a progeny test of rust-resistance. In addition, 7,100 seedlings of 'Kentucky 31' have been evaluated for resistance, and 472 (7 percent) apparently resistant plants have been identified. These will go to the field in the fall planting season.

Because of the great degree of susceptibility in these varieties and the potential for development of races of the pathogen that are more strongly virulent, all available germplasm of tall fescue should be evaluated for resistance to all known races. Any germplasm identified as resistant could be a ready source of rust-resistant plants, and it could be a potential source of resistance to new, more virulent strains that may develop.

3/ Murphy, H. C. 1935. Physiologic specialization in _Puccinia coronata avenae_, U. S. Dep. Agric. Tech. Bull. 433, 48pp.

ECOLOGICAL CONSIDERATIONS IN MANAGING AND UTILIZING TALL FESCUE

By T. H. Taylor and W. C. Templeton, Jr. [1/]

Tall fescue is a sod-forming long-lived cool-season perennial grass with short rhizomes. It is widely adapted in the southeastern United States, especially in the upper Southeast. Because of its soil and climatic adaptation and growth and nutritive characteristics, this species fills important forage needs of the region. We have observed over a long period that tall fescue grown in association with legumes results in forage of acceptable quality during the entire growing season. Because tall fescue is competitive with associated legumes, management practices should be directed toward favoring the particular legume or legumes used rather than the grass.

Several legume species are available which are ecologically adapted for growth in association with tall fescue. The use of summer-productive legumes is especially desirable, as summer growth of pure fescue with or without nitrogen fertilizer is of low quality as animal feed. Spring and late summer to autumn growth of fescue is of considerably better quality. We believe that one of the big advantages of this cool-season grass in the Southeast is its use as stockpiled pasturage for late autumn and winter grazing.

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BEEF CATTLE PERFORMANCE AND MANAGEMENT ON TALL FESCUE

By A. E. Spooner and Maurice L. Ray 1/

INTRODUCTION

Tall fescue has become an important perennial cool season grass in our pasture programs in Arkansas. The acreage in Arkansas has increased from about 25,000 acres in 1950 to over one million acres today with the greater part of this increase occurring in the last 10 years. I think that this tremendous interest in tall fescue is due primarily to the wide adaption and good production of fescue. It is adapted to most soils, except the deep sandy ones, throughout the state. It fits into a permanent pasture program with bermudagrass, bahiagrass, or dallisgrass. Fescue will produce enough forage to carry a cow and calf per acre if properly fertilized and managed.

There are a number of varieties of tall fescue available for use today. We have tested some of these and the results of one of our tests are presented in table 1.

TABLE 1.--Dry matter yields, as affected by different fertilizer levels, of four varieties of tall fescue and 'Southland' bromegrass at Fayetteville, Ark. Averaged over three legumes, four replications, and 4 years

(Tons of dry matter/acre)

Fertilizer per acre	'Kentucky 31' Fescue	'Goar' Fescue	'Fawn' Fescue	'Kenwell' Fescue	'Southland' Bromegrass
0:60:60	3.41	3.50	3.18	2.84	3.16
0:60:120	3.50	3.52	3.24	2.90	3.01
0:120:120	3.67	3.64	3.42	2.96	3.42
50:120:120	4.32	4.48	4.02	3.16	4.01
100:120:120	5.01	5.07	4.47	3.68	4.76
Species Average	3.98	4.04	3.66	3.11	3.67

The added effect of the nitrogen is apparent in these data even though each of the species was also grown with alfalfa, red clover, and white clover. 'Goar' and 'Kentucky 31' varieties yielded significantly more dry matter than the other species. 'Kenwell' yielded the lowest amount of dry matter of all varieties tested. We do not recommend 'Kenwell' for planting in Arkansas.

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Cattle Performance in Managed Programs

We are using tall fescue in three different beef cattle programs in Arkansas, the year-round cow-calf program, the backgrounding of steers program, and the finishing of beef steers on pasture with grain program. I shall discuss each program separately and give some of the data that we have accumulated over the past 18 years.

Year-Round Pasture Program

Our year-round pasture program for cows and calves utilizes tall fescue and white clover as the cool season species and bermudagrass, bahiagrass, or dallisgrass as the warm season species. The percentage of these species allotted per cow varies depending on the part of the state involved. In northern Arkansas, we allot two-thirds of the acreage as tall fescue and one-third as bermudagrass. In southern Arkansas, we allot one-half of the acreage as tall fescue and one-half as bermudagrass, bahiagrass, or dallisgrass. One-half of the fescue in each case is deferred for winter grazing. Some or our farmers in the mountains of Northwestern Arkansas are using all tall fescue and white clover for beef cattle. This is especially true where medium to high levels (4-5 tons per acre) of chicken litter are being used.

The data presented in table 2 are from one of our cow-calf year-round pasture studies at Hope in southwest Arkansas. One-half of the base grass in this experiment was tall fescue and one-half was common bermudagrass.

TABLE 2.--The effects of different stocking rates, fertilizer treatments, and creep-grazing on the percent calf crop weaned, weaning weights, and gains per calf on tall fescue and bermudagrass pastures, averaged over four years

Herd	Acres/cow	Fertilizer/ acre/year	Percentage of calf crop weaned	Weaning weights (pounds)	Gains/ acre (pounds)
A	2.00	60:60:60	81	455	182
B 1/	1.25	90:120:120	83	436	288
C	1.25	90:120:120	82	426	277
D 2/	1.25	90:120:120	88	443	311

1/ With summer creep of hybrid sudangrass.
2/ With winter creep of wheat and summer creep of hybrid sudangrass.

Our calf-crop percentages were lower than we like for them to be. This was primarily because we had to cull some cows from the herds during the 4-year period and replace them with young heifers. Since these cows did not receive any supplemental feed, many of the heifers did not breed back the first year after calving. We normally expect to wean calves from 90 to 95 percent of our cows. Our weaning weights were acceptable, but the gains per acre were lower than we normally expect, due primarily to the small calf crop. There were some advantages obtained from the creep-grazing; however, we question whether we can allot even 5 percent of our pasture area to creep-grazing. Our experience has shown that if you fertilize and manage you pastures properly, you do not need creep-grazing.

We noted that a large number of our cows did not shed their winter hair after being grazed on the highly fertilized fescue. At first, we were puzzled as to the cause, but finally decided that there was a copper dificiency. One of the better assays used to determine copper deficiency in cattle is analysis of the hair. We took hair samples from some of the cows, and the results are given below. We had cows in two herds that showed a primary deficiency level of copper and cows from the other two herds that showed a secondary deficiency level.

According to standards set by the Veterinary Science Society, normal copper content in cattle hair is 6.6 to 10.4 parts per million. A primary deficiency exists at 1.8 to 3.4 parts per million, and a secondary deficiency is present at 3.5 to 5.5 parts per million. These are the measurements of copper content, in parts per million, in the hair of selected cows from our herds.

Herd	Copper content
A	3.45
B	3.29
C	3.03
D	4.05

We selected certain of these cows and injected one group with a copper solution, fed copper sulfate to a second group, and fed trace mineral salt to a third group. It appears that we have eliminated the deficiency with all treatments.

Backgrounding Program

Backgrounding or growing beef calves from weaning to about 750 pounds has become common practice with many of our beef cattle producers. Tall fescue interseeded into bermudagrass sod and overseeded with 'Regal' white clover is one of the pasturing systems being used for this backgrounding. We wean our calves in mid-July at a weight averaging about 450 to 550 pounds and then put them on good-quality bermudagrass pasture that has been interseeded with tall fescue. The calves are left on these pastures for about 275 days. We attempt to maintain an average 0.80 to 1.00 pound daily gain with a carrying capacity of 2 to 2.5 animals per acre. The results of one of our studies on backgrounding are presented in table 3.

The average daily gains were lower than we normally expect on the combination of fescue and bermudagrass. We attributed this to the low quality of the bermudagrass forage at the time the cattle were started on the test. The test calves lost weight during this early portion of the period in each of the 3 years. The average daily gains were above 1.0 pound during the growing periods of the tall fescue and white clover. The main point to note from these data is the tremendous differences in gains per acre due to timing of nitrogen applications. There are over 100 pounds of gain difference between bermuda and bermuda-fescue, due to the nitrogen treatments. We consider 1.5 fescue plants per square foot to be the optimum for this mixture. We have maintained this stand in the treatment for bermuda-fescue.

TABLE 3.--The effects on steers of forage receiving nitrogen applications and the timing of the applications, averaged over two replications over 3 years

Nitrogen treatments to favor	Daily gain (pounds)	Steer days/ acre	Steer gains/ acre	Fescue plants/ 40 square feet
Bermuda----------------	0.86	495	401	27
Fescue-----------------	0.77	603	466	71
Bermuda-fescue---------	0.87	574	503	57
	Nitrogen application[1/] (pounds/acre)			
	February	June	August	October
Bermuda----------------	0	120	120	0
Fescue-----------------	120	0	0	120
Bermuda-fescue---------	60	60	60	60

1/ Total fertilizer applied= 240:120:240 per acre per year. 0:120:120 applied in September and 0:0:120 applied in February.

Finishing Program

After these beef steers have been backgrounded and weigh 700 to 800 pounds, we concentrate them (four per acre) on a good quality tall fescue-white clover pasture for a short period of grain feeding. We attempt to make them gain about 200 pounds during the 65 to 75 days on this program. We try to get about one-half of our steers to grade low choice by the time we send them to slaughter. The results of one of these finishing projects are presented in table 4.

TABLE 4.--Fescue-white clover pasture vs. drylot for finishing beef steers, on an average of two replications and 4 years

	Drylot	Pasture
Days on feed----------------------------------	66	66
Initial weight-----------------pounds----------	770	772
Final weight-------------------pounds----------	970	980
Gain per steer-----------------pounds----------	200	208
Average daily gain-------------pounds----------	3.03	3.15
Carcass grade[1/]--------------------------------	11.4	11.7
Grain per head per day---------pounds----------	21.4	20.8
Grain per pound of gain--------pounds----------	7.06	6.60

1/ Choice= 13; Good= 10.

These data favor, in all measurements used, the finishing of beef steers on high quality tall fescue-white clover pasture over finishing in drylot. Many of our producers are considering this type of program at present, and we should see an immediate increase in the number of beef animals being fed to slaughter weight and grade in Arkansas.

In conclusion, we feel that tall fescue is here to stay in Arkansas. We have been pleased with the results obtained in our total beef cattle program.

We recognize that there are problems in the management of fescue; however, we feel that the beneficial effects of the species greatly outweigh the bad effects.

WINTERING SYSTEM UTILIZING TALL FESCUE FOR BEEF COWS

By R. W. Van Keuren [1/]

A 7-year study has shown that beef cow herds can be successfully managed on tall fescue winter pasture in Southeastern Ohio without housing or supplemental feed. The system has wide application under Ohio Valley and Appalachian plateau hill conditions and in other areas with a similar climate and topography. The winter feed was supplied by round-baled first crop left in the pasture and the fall regrowth.

Several kinds of forage handling equipment, such as hay stackers and large round-balers, appear to be useful for the system. Tall fescue successfully withstood close grazing and trampling by livestock during the winter feeding period, roughly November 15 to April 15, and proved superior to other grasses studied. Periods of extremely wet conditions as well as snow occurred during the seven-year study. The nutritional level of the feed was adequate for mature pregnant beef cows without supplemental feed except for added minerals, salt, and water. The calves were generally dropped from late January to March on pasture.

The seven-year averages from the study were 2.3 and 2.0 tons per acre of first-cut hay and fall regrowth, respectively; a hay equivalent of 12 percent moisture; and 9.7 and 11.0 percent crude protein, respectively. Grazing time was 206 cow days per acre. Average live weight, condition grade, calving percentage, and general health of winter pasture cows were similar to that of barn-fed cows.

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TAKING THE PROGRAM TO THE FARMER

By

C. J. Kaiser, C. W. Absher, and L. W. Murdock 1/

INTRODUCTION

The Kentucky extension program of taking profitable concepts as well as action programs to the farmer in the basic areas of soils, plant management, and beef cattle production is carried out by an interdisciplinary land-grant college team. We wish to discuss the team's research and extension programs.

The Agricultural Experiment Station research group has centered on research problems through an active extension program at state, area, and county levels. The Cooperative Extension Service, using a topically oriented team, takes a total program to the extension agent and farmer. At the state level, this extension specialist team consists of three soil specialists, two plant-management specialists and three beef cattle specialists, together with farm analysis personnel and practicing and extension veterinarians. The extension agent is the frontline action man. He must have the total resources of the land-grant college system available to bear on the problems encountered in the field.

The team has initiated several interrelated programs. Three programs are related in detail in this report. Others in use are a fall fertilization program, beef performance testing, Kentucky pasture renovation, detail agent training areas, state and county forage councils, a four-phase beef production program, state and multi-county events, and on-farm test demonstrations of new grass and legume varieties.

Out of the necessity created by the ever increasing volume of knowledge, each student has become more and more specialized as he advances toward the goal of becoming a scientist. At the same time specialization is required for significant scientific achievement. Farmers demand that the best knowledge of interlocking disciplines be put together in a feasible system of production. With this background philosophy, we would like to share with you some of the programs that we have conducted as a soil, forage, and cattle team. The three major efforts discussed include a 365-day forage for beef system, a task force approach to the problem of grass tetany, and the Graze-More-Beef 4-H Project.

365-Day Grazing Concept

The basic rules for establishing a beef and forage system demand that optimum land use be considered and pointed out to a producer. Programs have

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been developed with the assumption that land used for grazing is being used at its optimum intensity.

Whenever a program is planned, it is kept in mind that a number of factors must be evaluated on each farm before a system can be instituted on it. Land, labor, capital, and management must all be considered, and the most important of these is land. In most cases this means keeping row crops on cultivatable land as often as conservation practices will permit and planning a beef and forage program on the reminaing pasture land, both in rotation and on a permanent basis. Therefore, realizing the potential economic return of the different crops. The crops must strategically placed on the land, using a soils map and as many aids as possible.

If all the land in Kentucky were farmed as intensively as possible, over 10 million acres of land would be planted with forage as its most intensive crop. At the present time, Kentucky only cultivates 60 percent of that which could be safely cultivated each year, and only 70 percent of the pasture and hay land is in a forage program. There is plenty of room for expansion with all crops, and only when considering land, labor, capital, and management can it be done properly.

Farmer with beef cow-calf herds in Kentucky may be able to cut winter feed costs by allowing their herds to graze all year. This could mean reduced labor and lower harvesting, storing and feeding costs. Kentucky is ideally positioned geographically for year-round grazing. Winters are not severe. Hills and wooded areas reduced the need for manmade shelters for beef-cow herds.

Coordinating the season with the nutrient requirements of the beef cow is the key to year-round grazing. In order to select the most desirable calving season, first consider the needs of the mature beef cow at various stages of production. Table 1 gives the daily nutrient requirements for dry and nursing cows.

TABLE 1.--Daily Nutrient Requirements for Beef Cows1/

Body weight (pounds)	Dry matter (pounds)	Crude protein (pounds)	Total digestible nutrients (pounds)	Ca	P	Vitamin A (1,000 IU)
			Dry and pregnant			
880	14	0.8	7.0	0.022	0.022	15.5
990	15	0.9	7.5	0.026	0.026	16.8
1100	17	1.0	8.4	0.026	0.026	18.2
			Cow with nursing calf			
880	21	1.9	11.7	0.057	0.046	36.0
990	22	2.0	12.4	0.062	0.048	38.5
1100	23	2.1	13.2	0.062	0.051	41.0

1/ National Research Council. Committee on Animal Nutrition. Subcommittee on Beef Cattle Nutrition. 1970. Nutrient requirements of beef cattle, 4th rev. ed., 55 pp. Nutrient Requirements of Domestic Animals, No. 4.

The prescribed nutrient levels for the nursing cow should support cows weaning 450 to 500 pound calves. Heavier milking cows should receive nutrients in excess of table values.

The nursing cow requires more than twice as much protein, calcium, phosphorus, Vitamin A and magnesium (not listed) as the dry cow and 60 to 70 percent more energy. Surplus or luxury feeding of dry cows can be expensive, complicate calving, impair milk production, and shorten the cow's useful life.

Working to define exact requirements for dry and nursing cows, J. N. Wiltbank compared two different levels of feeding before and after calving and observed the effect on reproduction. His findings are given in table 2.

TABLE 2.--Effect of Energy Levels on Reproduction

Percentage of cows showing estrus 90 days after calving	Percentage of cows pregnant at end of breeding season	Total digestible nutrients consumed	
		Before calving	After calving
		(pounds/day)	
22	20	4.5	8.0
85	95	4.5	16.0
95	95	9.0	16.0

He concluded that energy levels for the dry cow can be restricted but higher energy levels must be maintained after calving to allow for and promote desirable reproductive levels. The foregoing results illustrate the experimentally established fact that feed costs can be effectively reduced during a cow's dry period, but adequate levels of nutrition are necessary for production.

Concern for the Cow-Calf Pair

After the cow is bred, her demands decrease rapidly. After the calf reaches 3 to 4 months of age, it becomes expensive to feed the cow to feed the calf. According to Virginia data (R. E. Blaser, Virginia Polytechnic Institute and State University), calves restricted to only their mother's milk produced a pound of gain for every 44 pounds of total digestible nutrients (TDN) their dams consumed. However, when calves had access to high-quality feed and the cow's rations were restricted, calves gained a pound for each 17 pounds of TDN the cow-calf pair consumed.

Continuing the above work, Blaser found that Angus calves from 4 to 8 months of age on only their dams' milk gained the same regardless of whether the cows gained or lost weight during the test period. Also, the Virginia data demonstrated that young calves can use large amount of high-quality roughage. In their studies, calves on Angus cow's milk alone gained only 0.33 pound per day, but when a comparable group of calves had access to milk, silage, and hay they gained an average of 1.81 pounds per day. Thus, almost 1.5 pounds per day came from the forage each calf consumed. Therefore, our need for high-quality pastures in late summer and fall is demonstrated.

The foregoing discussion gives us a basis for developing the demand curve for the cow-calf pair as illustrated in figure 1. Immediately after calving, our attention is directed toward breeding the cow for the next year's calf.

When the calf is 3 to 4 months old, we must assure him of a highly palatable ration until he is weaned. A short (45 to 60 days) calving season is necessary so that the demand curve of the cow herd approaches that of a single cow, simplifying management.

Seasonal Distribution of Production

The cost of harvesting forage, storing it, and feeding it to the cow through the winter months often exceeds the feed cost for the remaining eight months (pasture season) of the year. Forage growth may be grazed in several forms. The following terminology for 365-day grazing is used in this paper: (1) pasture: forage growth grazed as it grows; (2) deferred: forage growth deferred for later grazing on site without cutting, "stored-on-the-stump;" (3) accumulated: forage growth accumulated (packaged) and left in place as round bales or stacks to be eaten in place, often with deferred growth.

The distribution of seasonal forage production to meet the cow herds nutritional needs on all 365 days of the year by the use of pasture, deferred, and accumulated grazing practices is an important factor in improving the profitability of the cow-calf enterprise. Labor, land, equipment, and storage costs must be kept low with little or no loss of efficiency in the utilization of the forage while still meeting the nutritional needs of the cow. The greatest net return to the beef cow enterprise can be expected from a forage system requiring little harvested and stored winter feed. This requirement dictates a spring calving program. The monthly nutritional needs of the spring calving beef cow herd are lowest during the winter and highest during late spring.

The seasonal distribution of pasture availability (figure 2) can be altered to some extent through the use of strategic fertilizer applications, plants with different growth curves, and irrigation. Altering the seasonal growth curve through these means is not sufficient to meet the nutritional needs of the spring calving cow herd. As illustrated in figure 3, other ways such as deferred and accumulated grazing methods along with pasture are needed to match the production of forage with the needs of the cow.

The objective of this system is to manage grasses and legumes to match the cow's nutritional needs. Planned pasture units must contain a grass or grass-legume combination which grows well and is of adequate quality to meet the cow's needs at time of use. Nitrogen-fertilized tall fescue managed for deferred and accumulated grazing is adequate for the dry beef cow during the winter period. Legumes increase the quality of the pasture during spring, summer, and fall. Fields managed to match the beef cow's needs as pasture, deferred and/or accumulated grazing are designed to reduce the amount of labor required per cow as well as hay storage and feeding costs.

Calender Management of Forage and Cows

A calendared forage system consisting of tall fescue and red, white, and ladino clovers and designed to meet the needs of the spring calving cow herd is outlined in figure 4. Three management units, with one or more fields per unit may be used. Field 1 consists of tall fescue with high nitrogen applications for winter grazing and field 2 consists of a perennial cool season grass with red, white, and ladino clovers for spring and fall grazing. Field 3 is a perennial grass pasture with red, white, and ladino clovers managed for early stored "reserve hay" and summer grazing of pasture and deferred growth.

A calendar for ration grazing is given in figure 5. Electric fences may be used to form temporary strips for grazing. These fences may be erected during the fall when the posts can be driven into unfrozen ground. Wires can be dropped to the ground each time a new strip is added and rolled up later when time and weather permit. With an electric fence, beef cows can be managed to consume all the deferred and accumulated growth of the strips. A good goal is to ration the grazing area (figure 5) into strips that can be completely grazed in 14 to 21 days. Stocking rate can be estimated by allotting each cow a daily ration of 15 pounds of accumulated forage plus the deferred growth on the area from which that forage was gathered.

Ration grazing of deferred and accumulated tall fescue is necessary for maximum utilization. Tall fescue forms a dense sod which will withstand grazing in late winter and early spring.

Calendar of Events, Field 1

Christmas to Easter Grazing

Date	Event
December 25	Begin ration grazing of accumulated and deferred growth. Allow 14-21 days per strip.
March 1	Calving begins.
April 15	Move cows and calves to field 2.
April 16	Apply 100 pounds of nitrogen.
June 20 (west Kentucky) . . . to July 4 (east Kentucky) . . .	1. Combine fescue seed if desired. 2. Mow, rake, and field-store as accumulated growth in loose stacks, compressed stacks, rolled stacks, or round bales.
July 15 . . . . to September 1	1. Apply 50 pounds of nitrogen per acre. 2. Based on soil test, apply lime, potassium, and phosphorus, or apply 0:50:50.
October	Erect electric fences needed for ration grazing.

Approximately 0.5 acre is needed per cow and calf unit for field 1. Field 2 is a pasture of tall fescue and red, white, and ladino clovers. It is grazed during the spring and fall. The peak of spring growth occurs during the period when the nutritional needs of the cow herd are greatest. The spring peak of production times the calving season to March and April.

Rotational grazing provides that cattle move from sub-pasture to sub-pasture in a cyclic fashion. While one sub-pasture is being grazed, others (at least two more) are allowed to recover. Movement from sub-pasture to sub-pasture must be more frequent in spring and early summer than later in the year. Rotation breaks parasite cycles, a valuable benefit. Continuous grazing of early growth may be allowed in field 2 to remove seed heads before development, aiding in keeping plants in a vegetative stage.

Calendar of Events, Field 2

Spring and Fall Grazing

Date	Event
Fecruary 15	Seed legumes if needed. Follow the Kentucky renovation plan.

Easter to Independence Day Grazing

Date	Event
April 15	Continuously graze entire field.
April 30	1. Begin rotational grazing. Rotate sub-pastures every 7-14 days, or as needed. 2. Calving season ends.
May 1	Clip if needed to remove seed heads.
May 20	Breeding begins.
July 4 . . . . to July 15	Move cattle to field 3. Based on soil test, apply lime, potassium, and phosphorus, or apply 0:50:50.

Labor Day to Christmas Grazing

Date	Event
September 15	Begin rotational grazing.
November 30	1. Wean calves. 2. Begin continuous grazing. 3. Begin continuous grazing of field 3 of needed.
December 25	Move cows to field 1.

Approximately 1 acre should be planned for per cow and calf unit for field 2.

Field 3 is managed for pastue and deferred grazing to meet the cow's nutritional needs during the summer dormancy period of cool season grasses. Therefore, the management must favor the growth of legumes. Early spring harvesting of tall fescue will favor clover production.

The first growth is harvested and stored to provide reserve hay to meet adverse weather conditions from season to season or year to year. Hay is fed from this reserve any time it may be needed to maintain the seasonal management schedule of each field as outlined in figure 4. The reserve hay provides the security necessary to insure the use of all the forage produced. Thus, stocking every year at the dry-year level is prevented.

Calendar of Events, Field 3

Date	Event
February 15	Seed legumes if needed. Follow the Kentucky renovation plan.
May 1	Harvest forage and store it in a convenient location for later use.

Independence Day to Labor Day Grazing

Date	Event
July 4	Begin rotational grazing of pasture and deferred growth. Rotate sub-pastures every 7-14 days, or as needed.

July 20	Terminate breeding.
September 15 . . . . and September 16	Return cattle to field 2. Based on soil test, apply lime, potassium, and phosphorus, or apply 0:50:50.
December	Continuously graze if needed or renovate if seeding to legumes is necessary. Fields 2 and 3 may be grazed together.

Approximately 0.5 acre should be planned for per cow and calf unit for field 3.

Task Force Approach to Grass Tetany

As the team worked on increasing forage and beef production, the problem of grass tetany (hypomagnesemia) became apparent. Field observations also indicated that the problem seemed to occur on better managed farms and that it appeared to be somewhat of a regional problem. Therefore, a survey of county extension agents was conducted to assess the importance of the problem and the areas of greatest incidence. Surveys indicated that grass tetany could cost Kentucky cattlemen as much as one million dollars annually in death losses alone. Surveys further suggested an association between the disorder and soil and/or forage production patterns.

By enlisting the cooperation of the State Diagnostic Laboratory, county extension agents, and local veterinarians, a more intensive survey of tetany afflicted herds has been made. Blood samples from affected cows, forage samples, and soil samples have been collected in the search for associated factors.

While searching for information, the close relationship between specialists, county agents, and veterinarians has helped to create an awareness on the part of the producers of the causes of tetany and the need for magnesium supplementation. Complete recommendations have been developed and are available from the College of Agriculture, University of Kentucky, Lexington, in a fact sheet, ASC-16 "Beef: Grass Tetany in Beef Cattle."

From the information obtained in these and other surveys as well as that found in the literature and gained from personal experience, different risk situations have been described concerning the probable occurrence of tetany. Rations have also been formulated to deal with the particular risk situation. The overall effort for the control of grass tetany has been relatively successful. Although the problem is still prominent, in areas where the education effort has been intensive the number of occurrences has been reduced sharply.

Risk situations and accompanying rations are listed below and in table 3.

Low-risk Situation

(1) Dry cows except in very late gestation
(2) Late May through October grazing

Mid-risk Situation

(1) There have been limited or no occurrences of tetany in the neighborhood
(2) Soil potassium tests are not high and heavy applications of nitrogen have not been made prior to grazing
(3) Cows are being fed adequate amounts of good to excellent quality hay
(4) Cows with yound calves or very near calving

(5) November through mid-May grazing (problem seldom occurs on summer pastures)

High-risk Situation

(1) Ration consists of lush growing grass, small grain pasture, or grass hay or haylage produced on soils testing high in potassium and/or fields that received heavy applications of nitrogen
(2) Cows with young calves or very near calving
(3) Area or farm with history of disorder
(4) November through mid-May

TABLE 3.--Suggested Feed Mixtures for Cattle to Prevent Grass Tetany

Ingredient	Mild-risk mineral mix	High-risk Supplement (free choice)	High-risk Supplement (hand-fed)
	(pounds)	(pounds)	(pounds)
Grain	--	39	66
Soybean meal	--	19	17
Steamed bonemeal	20	--	--
Dicalcium phosphate	--	10	10
Magnesium oxide	40	7	7
Salt, plain	20	25	--
Salt, trace mineral	20	--	--
Vitamin A premix 1/	--	--	--
Total	100	100	100
Expected intake/day	1	2	2-3

1/ Vitamin A should be added to each of the mixtures to provide approximately 30,000 IU's daily to each cow.

Another measure to be taken in a high-risk situation is to force-feed 1.5 to 2 ounces of MgO daily. This can be done by sprinkling the MgO on silage uniformly.

Some precautions for the high-risk free choice supplement are (1) intake may not be adquate; thus, the salt must be reduced; (2) fresh water should be available at all times; (3) cattle may miss eating for a day or two when highly palatable forage such as small-grain pasture is available. Therefore, the safest procedure in a high-risk situation is to hand-feed susceptible animals. Soybean meal can be removed from both high-risk supplements when pasture becomes green and lush in the spring.

Graze-More-Beef 4-H Project

Effective extension education requires the use of many different approaches to create an awareness of opportunities and problems in the minds of producers and to achieve acceptance of recommended practices. In an attempt to highlight high levels of forage production and grazing management, a Graze More-Beef 4-H Project was developed around the question of "How many pounds of beef can be grazed from an acre of land?"

In the project, 4-H'ers are guided to assess the producing capabilites of their land, to make necessary fertility amendments, and to select, establish, and produce desirable forage plants. Realizing that forage isn't pasture until it is utilized by the grazing animal, the 4-H'er is also directed to select and manage cattle so that they will remain healthy and make efficient use of pasture.

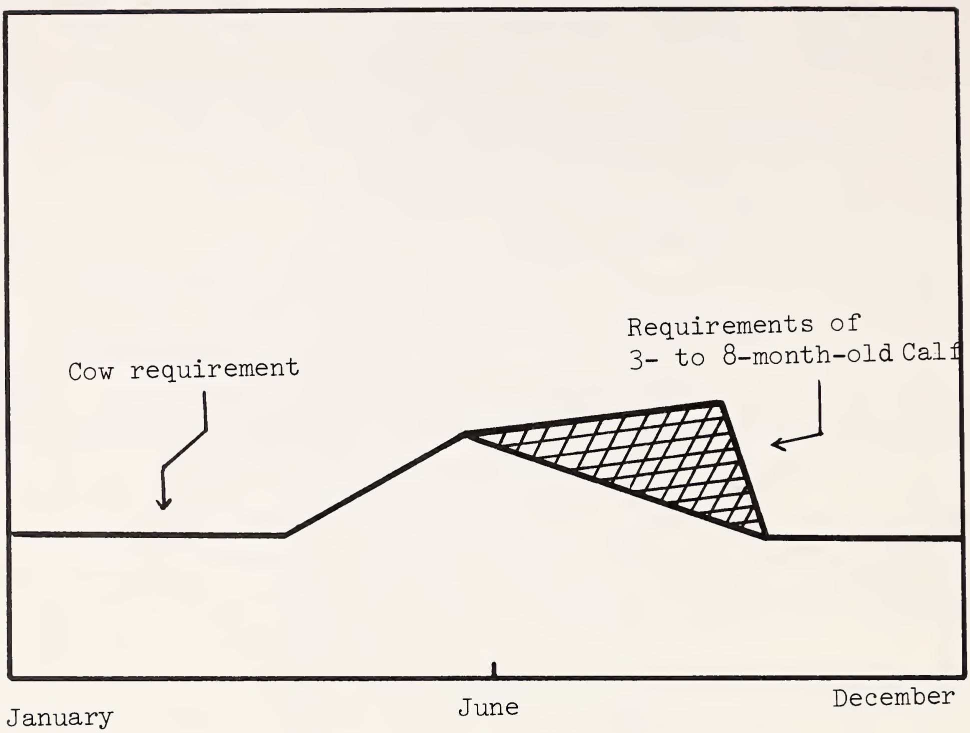

Fig. 1. Energy demand curve for cow-calf pair

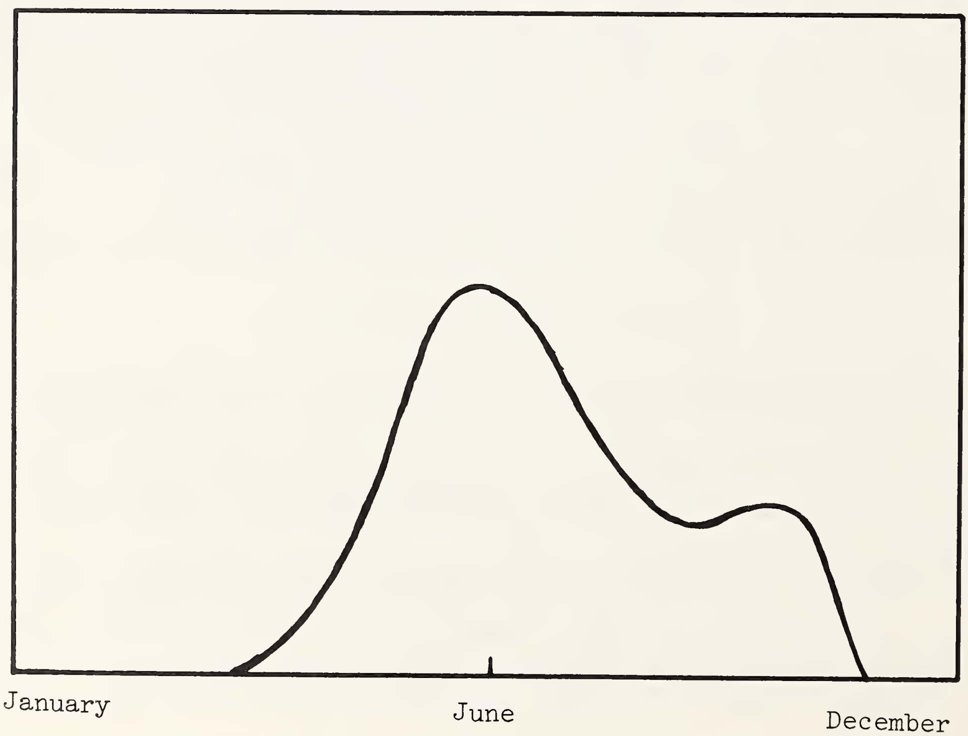

Fig. 2. Generalized pasture availability curve for tall fescue

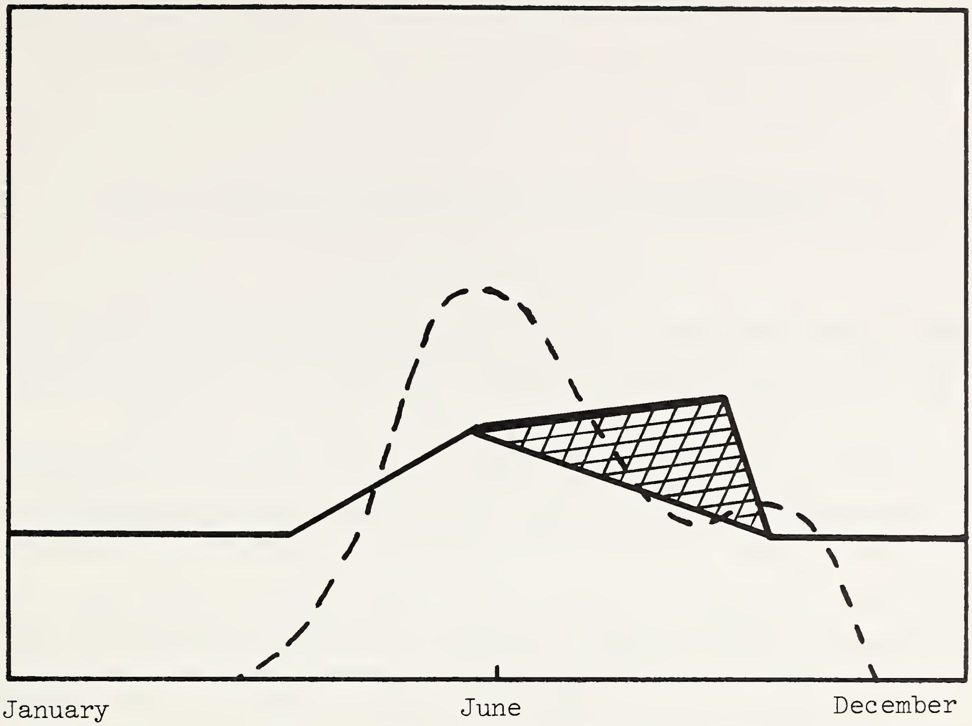

Fig. 3. Energy demands of spring calving cow synchronized with forage production

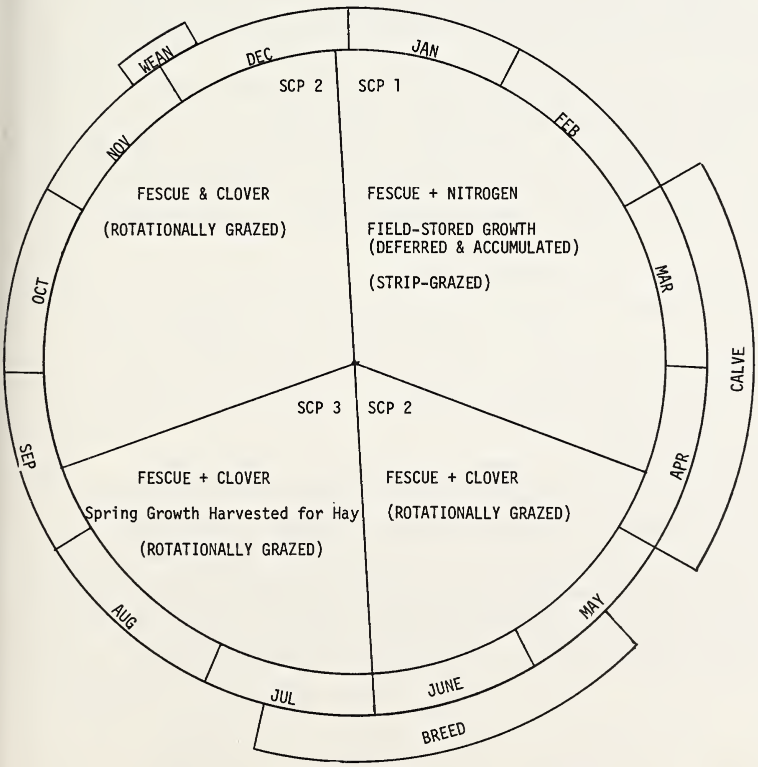

Fig. 4. Calendar management of forages and cows

Strip a	Dec. 25-Jan. 15
Strip b	Jan. 16-Feb. 1
Strip c	Feb. 1-Feb. 15
Strip d	Feb. 15-March 1
Strip e	March 1-March 15
Strip f	March 15-April 1
Strip g	April 1-April 15

Fig. 5. A method of ration grazing on accumulated and deferred growth

POTENTIAL OF SMALL GRAINS FOR PASTURE

By Fred C. Collins 1/

Under the present farming systems of this region, producers need supplemental forages during part of the year. Abundant, high quality forage can be produced during this time by small grains. The particular farming operation will dictate which psecies or mixtures of species is most suitable.

A typical cattle operation in this area heavily depends on forage production from fescue and bermudagrass. Normally, these permanent grasses and the native species will provide ample forage from mid-March to early November. The gap between early November and mid-March is when the need for small grains is the greatest.

Rye is the species that will produce the most forage during this period. The semi-winter-hardy cultivars such as 'Elbon', 'Bonel', 'Vitagraze', or 'Acco 811' produce quite well during the fall, winter, and early spring. The more winter-hardy types grow less during the winter months, but are more productive in the spring.

Wheat will generally provide good fall grazing, have some winter growth, and produce well in the spring. 'Ace' has been the highest yielding forage variety in this geographical area. Very little barley is grown in this ares; however, it is widely grown in Oklahoma. Its season of production is similar to that of wheat.

Oats grown in this region must be sown very early in the fall to take advantage of their capability for fall forage production. They usually become dormant in mid-November and remain dormant until mid-March when they can again make excellent growth. Ryegrass has a similar season. However, ryegrass will normally grow later into the spring (until June) and produce more total forage than oats.

Two other small-grain species which are being grown for forage are triticale and agro-triticum, intergeneric hybrids between Triticum and Secale and between Triticum and Agropyron, respectively. The largest amount of growth is produced in the fall by the spring-type triticales and in the spring by the winter types. The wheat-wheatgrass (agro-triticum) hybrids have the ability to grow late into the spring as does ryegrass.

Mixtures of the small grains should give maximum utilization of land specifically set aside for temporary pastures. Mixtures of rye and ryegrass plus burclover or arrowleaf clover have been the best combinations for total dry matter per acre, extended production, and growth during the winter months.

Emphasis needs to be placed on breeding small grains for forage production and breeding for resistance to Barley-Yellow-Dwarf-Virus and rusts. More management studies are needed on seeding small grains into sods of warm-season grasses and on how to avoid "sudden death," nitrate poisoning, and grass tetany.

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CREEP-FEEDING AND FEEDING STOCKER CATTLE ON PASTURE

By Maurice L. Ray [1/]

The pros and cons of creep-feeding have been widely researched and discussed for many years. This topic will likely continue to be of keen interest to those associated with the cow-calf phase of the cattle industry for a long time.

Basically, the calf receives the necessary nutrieints for growth and development from one or all of three sources, mother's milk, pasture forage, and creep or other supplemental feed. The economics of creep-feeding for a particular producer depends upon the abundance and price of the nutrient sources compared to the expected sale value of the calf. Other factors that are often less basic, neverthless, important as the positive advertising value of a sleek, glossy calf and dam and the production goals of the producer. The destination of the calf immediately after weaning affects the extent of value that creep-feeding has.

I view creep-feeding as a management tool that each producer must use according to his own circumstances. Creep-feeding is most likely to be economically profitable when there is a short supply of milk and/or forage and when the price of calves is high relative to that of grain.

At the Arkansas Agricultural Experiment Station, calves raised on an excellent high-quality forage regime did not use creep grain profitably, while those on a low-quality forage regime did. Creep-feeding was more profitable with calves of straightbred beef cows than with calves of crossbred cows with some dairy breeding who provided ample milk for their sucklings. Similar data have been reported from several other stations. In years with lower than normal rainfall, which naturally reduces pasture growth and subsequently milk production levels of cows, creep-feeding is more valuable. During seasons such as late fall and winter when pasture growth is minimal, the advantages of creep-feeding are often most evident.

Many producers see creep-feeding as a way to insure that replacement heifers have sufficient nutrition to reach puberty and settle at an early age. It also helps to prevent the constantly tugging, hungry calf from draining the mother to the extent that she fails to cycle and resettle soon after parturition. For these producers, creep-feeding provides insurance that their program will operate as smoothly and regularly as is biologically possible.

With the scarcity and high cost of fertilizers needed to produce abundant high quality pastures, many producers will be looking at creep-feeding as an alternative program or as a supplement to reduced pasture fertilization. Of course, the high cost of grain and protein supplements may offset the advantages and make the economics of creep-feeding doubtful in many operations.

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Another positives for creep-feeding is that the calves are feed-adjusted prior to weaning and are less affected by the trauma of weaning, shipping, and relocation and will more quickly adjust to maximum productivity in a back-grounding or feedlot program.

Many of the considerations previously mentioned apply to grain feeding of stocker cattle in a backgrounding program on pasture. Forage quality and quantity, condition of the calves at weaning, and market prices are among the factors that must be considered in determining amounts of grain to be fed to stocker calves on pasture.

Feeding grain to suckling or weaned calves on pasture will not be equally profitable for all cattlemen. Every producer must assess his own production circumstances and use the tool of "grain feeding on grass" in the manner that best serves his total program.

IMPROVING FORAGE QUALITY AND GAINS PER ACRE

By E. M. Evans [1/]

INTRODUCTION

Perhaps the titled subject should be modified or qualified by such words as efficiently or economically. This would eliminate, for now at any rate, such concepts as skyscraper feedlots encircled with large glass tubes teeming with hydroponic algae or perhaps enormous plastic domes placed over fertile pasture lands to assure optimal climatic conditions for maximum production. These ideas would not have seemed so fanciful in 1972, especially if postulated for the year 2000 or 2050. Since 1972 the energy crisis, world grain shortages, and accelerating inflation, with only feeble corrective actions, have combined to cause serious reconsideration of our position. With widespread famine in the world, can we ethically feed grain to cattle knowing that the end product will feed one rather than five persons? Sixty-two percent of the world's food is directly from grain or see, and population trends indicate the proportion will surely increase.

The markedly higher costs of fertilizer, concentrate feeds, labor, and machinery balanced against lower prices for beef, due in part to market disruptions from price controls, indicate a necessity for producing more of our beef on forages as advised recently by an outstanding authority on cattle feeding, Duane Flack of Greely, Colo. We in the southeastern United States have the capability of following through in this regard. We have vast areas better suited for the growing of forage than for more intensive use. We have favorable rainfall and a climate that permits plant growth most of the year.

We have an array of forage plants well-adapted to our area from which to select. There has been a great improvement in the quality of cattle in recent years, so our cattle now compare favorably with those of other sections. If we manage these factors advantageously, we should be in the cattle business for many years.

Allowing for some favorable adjustments in the prices of feeds, fuel, and fertilizers, the outlook is for a tight economic situation in the area of beef production. Inflationary pressures on land values, labor costs, and interest rates will likely continue for some time. A realistic response to the prevailling situation would be a fine tuning of management factors to better utilize available resources.

I will review some of the recent research in Alabama to illustrate possibilities for refinements in management and, hopefully, point up direction in which we may wish to go in the near future. Most of the information has been published in bulletins, and copies are available to thos interested in more details of the research.

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Beef-Brood Cow and Calf Grazing System

Systems that minimize the costs of wintering by reducing the requirements of harvested and stored feed and emphasize grass-legume mixtures rather than fertilizer nitrogen appear to have the advantage in Alabama under current conditions (4, 10, 11).[2/] On heavy soils, the best systems involve wintering on hay followed by legume-grass grazing in spring and summer.

Confinement Systems

Confinement systems offer maximum use of the land for forage production (7) but land prices must rise greatly before these systems will be more economical than conventional systems in Alabama (2). Either a large increase in land values or a real breakthrough in forage yield could change this picture and make confinement more attractive.

Research on a semiconfinement system or blended cash crop plus cow and calf production shows that such a system is feasible on productive land (3, 5). This system requires careful timing of operations, a high level of management, plus a considerable investment in facilities. It will become more attractive is the trends mentioned earlier continue.

Cross Breeding

Crossbred claves from Charolais or Brown Swiss bulls on an English breed of cows gain faster and are heavier at weaning (12). They are also leaner and must be older at finish to grade high, as carcasses are graded on fat depositions. The producer who sells such calves as stockers or feeders benefits because the weight advantage is more imporatnt than grade for these types of calves.

Stocker Calves

Our most successful forage programs for stocker calves involve cool-season species, either annuals (9), overseeded annuals on perennial swards, or perennials. Feeding grain on perennial forage pastures increases gain, but generally is a break-even proposition from an economic standpoint. One of the main hurdles in the stocker systems is the gaps in high-quality forage available for grazing. Various systems have involved feeding silage in confinement or hay on pasture during periods of inadequate forage.

Rates of gain range from about 1 pound per day on perennial summer grasses and tall fescue grazed in the fall to about 2 pounds on small grains or annual grass-clover swards.

Slaughter Cattle Production

With cheap gain and little interest in pollutants from feed lots, there was no great impetus to finish cattle on forage. This situation has changed on both counts, at least temporarily, and there has been renewed interest in finishing cattle on forage. Examples of work in Alabama (1, 6) show that it can be done satisfactorily with English breeds and crossbreeds. If the later-maturing exotic crosses are finished this way, the slaughter grade suffers, even if carcass yields, tenderness, and flavor do not. Fains of 1½ to 2 pounds

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[2/] Underlined numbers in parentheses refer to items in "Literature Cited" at the end of this paper.

per day permit addition of 300 to 400 pounds per steer for the grazing season. Good and choice carcasses have been produced from calves that weighed about 550 pounds initially. Crosses with exotics would not grade at this level.

Legumes in Pastures

We can grow abundant forage under usual conditions in Alabama. Yields of 'Coastal' bermudagrass hay range from about 5 to 6 tons per acre with 200 pounds N to 10 tons per acre with 600 pounds N. Silage yields of 15 to 20 tons can be made with good management. We have a great opportunity to increase the length of the grazing season by overseeding annual legumes and small grains on perennial summergrass swards. We can renovate and reintroduce perennial legumes into tall fescue pastures. The potential is great and well-documented. The primary problem is fitting this potential to logical beef production systems that will produce a product acceptable to the consumer at at profit to the producer.

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BREEDING AND POTENTIAL USE OF ANNUAL CLOVERS

By W. E. Knight [1/]

INTRODUCTION

In recent years, interest has developed in the utilization of clovers in pastures. The energy crisis and subsequent high-priced mineral nitrogen have stimulated part of this interest. However, a desire to develop and use forage legumes was growing before the energy crisis.

Producers and scientists have been emphasizing better quality forage with better seasonal distribution. They have been developing grazing systems in which the cow harvests most of the feed consumed with minimum amounts of feed harvested, stored, and fed back to the animal. There has also been an emphasis on better use of our land resources to produce food and fiber. Supporting this research, recent economic studies have stressed that yield alone does not necessarily make a practice economical, but instead it is the amount of quality forage (measured in energy units) consumed and converted into beef and milk (11, 12)[2/] that is important.

Annual Clovers as Forage

The annual clovers are widely adapted and fit well into many grazing systems (13, 21, 24, 38, 39). When the wide adaptation and potential of the annual clover species are considered, it is apparent that the scientific effort spent to develop insect and disease resistant and more reliable reseeding and forage production and the consequent improvements in preformance have been relatively small. Too frequently in the past, the tendency has been to discard the crop rather than attempt to solve a particular production problem.

Breeding Objectives

Our research in improving annual clovers by breeding began in 1958. Initial efforts were devoted to improvement of crimson clover, *Trifolium incarnatum* L. In 1963, arrowleaf clover, *Trifolium vesiculosum* Savi., was added to our program, and in 1965 subclover, *Trifolium subterraneum* L., was included. Since 1970, subclover has been of major importance in our program. For some time, we have been intrigued by the rapid growth and quick recovery after clipping of berseem clover, *Trifolium alexandrinum* L., and we have worked

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2/ Underlined numbers in parentheses refer to items in "Literature Cited" at the end of this paper.

a little on selecting for winter-hardy types of this species.

Our breeding objectives in working with crimson clover have been to (1) improve fall and winter growth (30, 33); (2) determine the potential of inbreeding and hybridization; (3) develop seed-shattering and lodging resistance; (4) develop resistance to the clover head weevil, Hypera meles Fab. (48-50, 52); (5) select for virus resistance; (6) determine the value of high-temperature-induced dormancy as a survival mechanism; and (7) accumulate useful genetic markers.

While breeding arrowleaf clover, we have worked to (1) improve early emergence and uniform stand establishment; (2) improve late-spring and early-summer persistence; (3) improve drought tolerance; and (4) select for resistance to root and virus diseases.

With subclover, we have been trying to select for good forage yield and distribution; (2) select for reliable reseeding; and (3) select for resistance to various diseases, including viruses, scorch, and mildew.

Our breeding objectives while working with berseem clover have been to (1) select for winter hardiness, and (2) select for resistance to leaf diseases.

Potential Use of Annual Clovers

Grass-clover combinations. Crimson clover is one of the most widely adapted winter-annual clovers (20, 21, 38, 39). It grows over a wide range of soil conditions, thrives in association with other crops, and fits well into many crop sequences. In Mississippi, results of grazing studies at the Brown Loam Branch Experiment Station, Raymond, and South Mississippi Branch Experiment Stations, Poplarville, indicate that crimson clover makes a profitable combination with ryegrass, oats, or wheat (9, 15-17). In 1952, winter pastures of ryegrass and crimson clover produced the heaviest yield of beef and returned the greatest profit (15). This combination of forages produced over three times as much profit as from fescue alone. These tests emphasized the value of the associated legume in grass mixtures as insurance against loss from winterkilling of oats or ryegrass. Crimson clover is the most winterhardy of the winter legumes and would provide forage if the grass is lost from winterkilling or disease (8).

In recent years, crimson clover has been used successfully in grazing systems for finishing cattle on pasture (47). At the Texas A & M University Agricultural Research and Extension Center in Overton, 'Dixie' crimson clover and ryegrass when overseeded on common bermudagrass produced average daily gains of 1.84 and 2.56 pounds for heavy and light stocking rates respectively over a 151-day period.

Through the years, reseeding crimson clover and 'Coastal' bermudagrass have been one of the most productive combinations (21, 31, 38, 39, 51). This mixture requires minimum maintenance compared to annually seeded forage crops and according to Knight in 1968, has been successfully used in beef cattle operations for 20 years or more (29).

The total acreage of crimson clover is not known. The domestic disappearance (seedsman's term for sales) of seed reached a peak in 1951 with 38 million pounds of seed purchased in the United States. Since 1960, sales have declined from an annual level of 17 million pounds to 10 million pounds in 1970. Several factors contributed to this decline. Clover seed weevils caused a sudden increase in seed losses in the mid-1950's. More than 60 percent of the crimson clover acreage was in reseeding cultivars that did not require annual reseeding, reducing demand for seed. The price of seed declined as seed

production moved to the West and yields of seed per acre increased. During the 1960's many producers emphasized using mineral nitrogen to get high yields of grass forage, reducing interest in clover as a source of nitrogen in pastures.

Since 1965, considerable emphasis has been placed on arrowleaf clover (6, 22, 27, 36), and much land formerly planted in crimson clover is now seeded to arrowleaf clover. Unless some of the hazards involved in the production of arrowleaf clover are overcome, however, crimson clover will continue to be the reliable standby in the winter-grazing program in the South (29). Crimson clover has several advantages over arrowleaf. It is easier to establish, and it is easier to inoculate effectively. Crimson clover will produce more fall and winter forage then arrowleaf clover, if it is planted at the optimum time. Crimson seed is less expensive (32, 34) and it reseeds more reliably.

Since its introduction in 1956, arrowleaf clover has been successfully grown from east Texas to South Carolina and southward from Arkansas and Tennessee to the Gulf of Mexico. Acreage has expanded most rapidly in Alabama, east Texas, and Arkansas. Some arrowleaf clover is grown for seed production in western Oregon. A survey in 1971 showed over 70,000 acres of arrowleaf clover in the United States, and acreage is expected to increase, particularly on droughthy upland soils of the lower South where white clover does not persist.

Farmers have rapidly accepted arrowleaf clover for several reasons. Arrowleaf has a long productive season, giving high yields and quality. This clover gives a high percentage of hard seed providing good reseeding ability. Also, the Soil Conservation Service, state experiment stations, seed trade, and certification associations launched a highly effective promotion program. Crimson clover generally produces more fall and winter growth than arrowleaf clover, but the latter remains productive 6 to 8 weeks later in the spring.

Arrowleaf gives high-quality forage. Cell-wall content remains relatively low until bloom stage even though stem percentage may be high (25). Digestible dry matter remains high until maturity in late May or June (28). Cattle grazing arrowleaf clover seldom suffer from bloat.

Arrowleaf clover is ideally suited for extending the grazing season of small grains. Rye-ryegrass-arrowleaf clover pasture can provide high-quality forage during April and May (4). On hilly Piedmont soil in central Alabama over a 4-year period, yearling steers grazed continuously on ryegrass-'Yuchi' arrowleaf clover from November 24 to June 6 at a stocking rate of 0.4 to 0.8 steers per hectare. Gains were 182 kilograms per steer, with an average daily gain of 0.91 kilograms (4). In the Tennessee Valley in northern Alabama, yearling steers grazed from October to late December and from early March to June. Gains were 0.91 kilograms per steer on small grains alone (18).

Arrowleaf clover can be overseeded in autumn on perennial warm-season-grass sods to furnish grazing in late winter and spring. On clipped plots of bermudagrass sod in Georgia and Mississippi, crimson has been more productive than arrowleaf clover (7, 32). However, in Alabama, arrowleaf yields were higher than crimson on both bermudagrass and bahiagrass sods (24).

Arrowleaf will usually reduce spring growth of the summer grass, and if the clover is not removed, grass stands may be injured. Continuous grazing prevents heavy clover accumulation and shading of grass. Overseeding of 'Coastal' bermudagrass with 'Yuchi' arrowleaf in central Alabama furnished clover for grazing from early April to July with no damage to the grass (23). Beef calf gains on this sward were superior to those of calves grazing grass alone.

Clovers as a source of nitrogen. Research at the Mississippi Agricultural and Forestry Experiment Station, Mississippi State, in 1968 and 1969 showed that clovers grown with 'Coastal' bermudagrass produced much higher yields of grass forage with better quality and seasonal distribution (32, 35, 40) than grass grown alone. 'Coastal' bermudagrass grown following crimson and arrowleaf clovers in the same pastures produced approximately 1 ton of dry forage per acre more than the grass check which received 200 pounds of nitrogen per acre (table 1). The clover which grew from volunteer stands on these plots was an additional bonus.

TABLE 1.--Dry forage yields from clovers overseeded in 'Coastal' bermudagrass sod 1968-69[1/]

(Pounds dry matter per acre)

Forage combination	Clover	Grass	Total
Crimson clover and bermudagrass	2,660	9,770	12,430
Arrowleaf clover and bermudagrass	2,170	9,170	11,340
Red clover and bermudagrass	5,600	4,440	10,040
White clover and bermudagrass	6,520	3,680	10,200
Check:			
Bermudagrass with no clover and no N.	---	2,340	2,340
Bermudagrass with no clover and 200 lb. N/acre/yr.	---	7,740	7,740

1/ Annual clovers were from stands volunteered in 1969. Red and white clovers were from initial seeding.

Subterranean and crimson clovers grown with ryegrass and fertilized only with phosphorus and potassium produced the same total forage as ryegrass grown alone and fertilized with 120 pounds of nitrogen per acre (table 2). The mixtures produced almost twice as much forage during the winter as ryegrass alone. Ryegrass in mixtures did not winterkill, whereas, ryegrass alone which received nitrogen severely winterkilled.

TABLE 2.--Dry forage yields from ryegrass-clover mixtures, Mississippi State, Miss., 1971-72

(Pounds dry matter per acre)

Components	Fall	Winter	Spring	Total
Ryegrass and subclover:				
Clover	648	834	1,959	3,442
Grass	1,092	863	2,287	4,243
Total				7,685
Ryegrass and subclover:				
Clover	527	1,055	2,973	4,555
Grass	1,142	979	2,081	4,202
Total				8,757
Ryegrass check[2/]	2,262	1,066	4,803	8,132

1/ Received 500 lb. 0:20:20/acre at planting.
2/ Received 120 lb. N/acre in 2 applications.

Similar results were obtained in the 1971-72 season with fescue-clover mixtures (table 3). Total production from a clover-fescue mixture was superior to that from nitrogen-fertilized fescue. Winter production of the clover-grass mixture was much better than that of grass alone.

TABLE 3.--Dry forage yields from tall-fescue-clover mixtures, Mississippi State, Miss., 1971-72
(Pounds dry matter per acre)

Components	Fall	Winter	Spring	Total
Tall fescue and subclover:1/				
Clover	1,230	1,182	1,966	4,380
Grass	346	489	1,748	2,585
Total				6,965
Tall fescue and crimson clover:1/				
Clover	1,063	1,898	2,201	5,162
Grass	291	539	1,402	2,233
Total				7,395
Tall fescue check2/	1,010	1,218	4,303	6,533

1/ Received 500 lb. 0:20:20/acre at planting.
2/ Received 120 lb. N/acre in 2 applications.

Clovers to improve forage quality. Generally, perennial grasses fertilized with heavy quantities of nitrogen produce more dry matter and total digestible nutrients per acre than do permanent apstures composed of legumes and grasses. However, the use of large quantities of nitrogen on grass pastures is questionable economically under many mangement systems (10, 19, 45). The amount of quality forage consumed and converted into beef and milk is more important than forage yield in making a management practice economical (5, 11, 12, 41).

Everyone agrees that legume forage is highly digestible, providing from 60 to 80 percent digestible dry matter. Animals eat much more of legumes or grass-legume mixtures than grass alone, even when the grass is fertilized heavily. Legumes added to grass usually compare favorably in digestibility to grass grown alone and fertilized with 100 to 200 pounds of nitrogen (11, 32, 35).

Some of the less obvious yet valuable benefits of clover in pastures involve animal health, milk flow, calf weaning weights, and conception rate. The classical research in Florida of Koger et al. (41) showed an increased pregnancy rate for lactating cows grazing white clover-grass pastures compared to grass alone. The lower pregnancy rate in cows on grass pasture was a result of the failure of nursing cows to come into estrus rather than failure to conceive when bred. In addition to higher pregnancy rates, calf weaning weights were also greater on grass-clover mixtures. Koger et al. concluded that the cost of producing beef in a cow-calf enterprise from a grass-clover sward was approximately 60 percent of that on pure grass.

Problems with fescue-foot, grass tetany, and similar diseases are minimized when grass-legume mixtures are properly utilized.

Clover seed, a bonus. With an increased demand for seed, many farmers can save seed to use for themselves or to sell and can realize a substantial bonus. This has been done successfully with crimson and arrowleaf clovers. Mowing and removing excess growth have caused increased seed yields (46).

Limitation to Realizing the Potential

Several things are basic to success with clovers. Most farmers who have difficulty maintaining legume stands have problems with soil fertility or in their management practices (1, 2, 42, 43, 53). Legumes require more mineral nutrients such as phosphorus, potash, and calcium, and more restrictive management than grasses. A good rule is to manage the pasture to favor the legume.

The following are essential practices in establishing and maintaining clovers.

1. Use high-quality seed of a named, certified variety. Specify scarified seed for the arrowleaf clovers (3).
2. Inoculate the seed with a specific inoculation culture for the species to be planted. Stick the inoculant to the seed immediately before planting, using a sugar or syrup solution (14).
3. Plant at the optimum time.
4. Fertilize according to the soil test's results, and lime to the pH recommended. If you plan to harvest or you want reseeding (volunteering), add boron (42).
5. Manage mixtures to favor the clover.
6. Remove grass residues by close grazing, mowing, or burning when establishing clovers in grass sods (26, 32).
7. Protect early-established stands from insects (44).
8. Use it or lose it: fall and winter production of annual clovers is primarily leaves and petioles which must be used to avoid serious losses from disease (37, 54).

The use of adapted annual clover varieties, both now and as new varieties are developed in the future, should result in large economic gains to the livestock industry in the Southeast. Both beef and dairy farmers would profit from cheaper nitrogen fertilizer, an extended grazing season, increased forage production, and quality, better use of land resources, a stimulation of milk flow, higher calf weaning weights, and better calving percentages.

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POSSIBILITIES FOR THE GENUS PHALARIS IN THE SOUTH

By Carl S. Hoveland [1]

INTRODUCTION

Cool-season perennial grasses such as tall fescue and orchardgrass are the basis of pastures in the upper South. 'Kentucky 31' tall fescue is also widely grown in the lower South, but this cultivar is winter-dormant and production during the critical winter period is low. A dependable winter-productive perennial pasture grass is needed in the lower South for grazing beef cows and calves, reducing the amount of stored feed required.

Current Uses of Phalaris

Vose (16),[2] in a review article published in 1959, pointed out the potential of two *Phalaris* species — reed canarygrass (*Phalaris arundinacea* L.), and hardinggrass, koleagrass, or phalaris (*Phalaris tuberosa* L.). Reed canarygrass, used to some extent in the northern United States (11), has been tested by many researchers in the South. One variety, 'Auburn' reed canary, was selected by P. B. Gibson in Alabama from highly persistent plants of local and introduced strains and released in 1952. However, reed canarygrass has not been planted to any extent in the southern United States and has had only limited use for waterways and areas subject to flooding. Although reed canarygrass generally persists well, it is difficult to establish, produces poorly in the winter (7), and is low in palatability (1). As far as this author knows, no breeding programs with this grass are currently underway in the South.

Phalaris tuberosa L., originally classified as *Phalaris aquatica* L., (11) is widely used for pasture in Australia, where it is commonly known as "phalaris." It is also an improtant grass in Mediterranean-climate areas of California where it is known as "hardinggrass". It is also grown in Chile, Uruguay, Argentina, South Africa, New Zealand, and a number of Mediterranean countries. This grass will be referred to as "phalaris" in the remainder of this paper.

Breeding of Phalaris

Breeding programs. Phalaris has fascinated a number of researchers in the South over the years. Trials with Californian and Australian phalaris cultivars

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2/ Underlined numbers in parentheses refer to items in "Literature Cited" at the end of this paper.

have generally been disappointing. California cultivars of koleagrass and hardinggrass generally have poor persistence when grown in humid areas (7). However, one improved phalaris cultivar, 'TAM Wintergreen', has been released in Texas (3). Surviving plants from two introductions were selected and increased by M. J. Norris at the Texas A & M University Research Center in the McGregor Blacklands of north central Texas. This cultivar is characterized by superior winter growth, good summer-drought resistance, high palatability, and no indications of being toxic or causing poor animal performance (13). E. C. Holt[3/] estimates that there are a "few thousand acres" of this cultivar growing in Texas and that "significant acreages have been planted, but much of this failed to become established." Improvement programs with this species are currently underway in Alabama, South Carolina, and Texas.

In 1959, at the suggestion of A. A. Hanson, I started screening phalaris plant introductions in Alabama. We found large differences in winter productivity among the inreoductions. Several unselected phalaris introductions produced nearly twice as much winter (November-February) forage as 'Kentucky 31' tall fescue or 'Auburn' reed canary grass over a 4-year period in central Alabama (6). Space-plant nurseries of phalaris introductions exhibited a large amount of genetic diversity for winter productivity, morphology, maturity date, and summer dormancy (5). Australian workers have also reported on the rich genetic diversity for these characteristics in phalaris (4, 15).

In 1969, C. D. Berry initiated a phalaris-grass breeding project at Auburn University, Auburn, Ala. to develop an adapted cultivar. In the initial stage of the program, previous selections were progeny tested in yield trails for seedling vigor, winter productivity, decumbent growth habit, late maturity, and persistence. Superior selections were combined into four phalaris synthetics to be further tested at several locations in Alabama. Performance of the synthetics is encouraging, as illustrated by second-year yields of 'synthetic-2' obtained from one test (table 1).

TABLE 1.--Seasonal forage yields of phalaris and tall fescue in year after establishment (winter of 1973-74), with 200 pounds N/acre, Tallassee, Ala.

(Pounds per acre)

Harvest date	Koleagrass	'Synthetic-2' phalaris	'Wintergreen' phalaris	'Kentucky 31' tall fescue
Sept. 11	930	2,290	950	1,410
Oct. 10	770	1,700	800	1,480
Nov. 29	740	980	540	550
Jan. 21	1,110	1,060	910	490
Feb. 12	820	830	820	730
Apr. 16[1/]	1,210	1,240	2,540	1,100
Total	5,580	8,100	6,560	5,760

1/ Severe March drought accounts for low yields in the April 16 harvest.

3/ Personal communication with E. C. Holt, professor of forages, Department of Soil and Crop Sciences, Texas A & M University, College Station 77843.

Phalaris Synthetics

Winter production of phalaris 'Synthetic-2' is superior to that of tall fescue. Another synthetic has proven superior on heavy clay soil in the Black Belt. Autumn production of both 'Wintergreen' and koleagrass has been considerably less than that of 'Synthetic-2'. Persistence of the synthetic is good in contrast to the stand losses common to hardinggrass and koleagrass from California. Production of the phalaris synthetics in the winter and early spring of the establishment year is two to three times that of 'Kentucky 31' tall fescue. Similar results have been obtained in replicated yield trials at five other locations in Alabama. Limited data suggest that two of the phalaris synthetics are more responsive than 'Kentucky 31' tall fescue to higher rates of nitrogen fertilizer.

Current progeny tests of several hundred additional selections are even more encouraging for autumn and winter forage production. These progeny test plots, harvested monthly from September through April over 2 years, promise even better autumn and winter forage yields than the earlier synthetics.

We have attempted to determine morphological and physiological parameters responsible for winter forage productivity in phalaris genotypes. Winter productivity of certain of these appears to result from rapid development of new leaves and rapid leaf expansion during short periods of favorable temperature, possibly aided by a supply of readily translocated carbohydrates (8). Phalaris genotypes did not differ in photosynthetic rates per unit area of leaf surface at several temperatures.

Establishment. The poor seedling vigor of reed canary grass is also a problem with California phalaris entries such as hardinggrass and koleagrass (16). To illustrate the problem, 'Kentucky 31' tall fescue can be successfully established with a companion crop of rye for forage while koleagrass cannot (9). Fortunately, there are large differences among phalaris genotypes in seedling vigor, and the synthetics currently being tested are much better than hardinggrass or reed canarygrass. In our screening program, we have also found genotypes that germinate satisfactorily at high temperatures and lower soil moisture. If these characteristics can be incorporated into improved synthetics, it should make establishment more dependable.

Persistence. Hardinggrass persists for many years in areas such as portions of California which have hot, dry summers and winter rainfall, but it is difficult to maintain a stand in the hot, humid summers of the South. Late spring and summer defoliation of hardinggrass and koleagrass in Alabama resulted in reduced stands and reduced autumn forage yields (2). Defoliation in summer encouraged some summer growth and reduced carbohydrates needed for initiation of autumn growth. Dormancy of these grasses in summer may allow heavy summer growth of weeds. The improved sythetics form a more dense sod than hardinggrass which helps resist weed competition. However, most summer weeds can be controlled in phalaris with Treflan herbicide.

Summer persistence of the synthetics has been good, resulting in rapid growth of forage in early autumn. The summer dormancy of phalaris may be helpful in maintaining stands of perennial legumes in grass-clover pastures. We are currently studying phalaris-legumes, phalaris-dallisgrass, and phalaris-tall fescue mixtures.

Although summer persistence may be an important problem in the lower South, winter hardiness will become more important as plantings are made further north. Whereas winter survival of koleagrass and hardinggrass is poor in northern Alabama, we have had no stand losses on our improved synthetics.

Until further testing is done, we cannot determine how far north these grasses are adapted. It does appear that we can develop phalaris with improved winter productivity and yet sufficient winter hardiness for central and probably northern Alabama.

Pest problems. Thus far in our testing program, we have not observed any serious disease or insect problems with phalaris. However, it appears that stunt, lance, and stubby root nematodes can be a serious problem on phalaris as on tall fescue, resulting in reduced yield of older plantings. Unless we are able to incorporated nematode resistance into phalaris, it appears that this grass will be restricted to clay soils or wet sandy loam soils where nematodes are less of a problem. Phalaris has performed especially well on these soils and shows excellent promise on prairie soils of the Alabama Black Belt.

Forage quality. Digestible dry matter (DDM) and protein content of phalaris remains high over the productive season (6). DDM values have ranged from 76 percent in February to 73 percent in March and 65 percent in late April. In Texas, DDM of 'Wintergreen' phalaris was 64 percent as compared to 71 percent for oats (13). Crude protein values of 20 to 25 percent also indicate high forage quality.

Palatability of hardinggrass phalaris was high in Alabama (1), and daily gains of steers on 'Wintergreen' phalaris in Texas were satisfactory but not as high as for animals on oat pasture (13). We have not obtained any animal gain data on phalaris yet in Alabama but expect to have sufficient seed for a grazing experiment with a phalaris synthetic during the 1974-75 season.

Alkaloids are a potential problem in this grass genus (10, 16). Not only can alkaloids reduce palatability, but they can also reduce animal performance and cause a disorder known as "phalaris staggers" in Australia. The disorder is most common in sheep but can also occur in cattle. Ronphagrass, a phalaris hybrid, has caused the toxicity symptoms in sheep in Florida (14).

We have found considerable differences among phalaris genotypes in total alkaloid content. One interspecific hybrid of *P. tuberosa* X *P. arundinacea* from Australia was unusually high. We are now trying to identify specific alkaloids and determine the effect of environment on concentration in phalaris synthetics being tested. Alkaloids may not be a serious problem for cattle grazing phalaris in the South, but we need to be sure before a new cultivar is released.

Seed Production

Phalaris seed is mature and ready for harvest by late May or early June in Alabama. This is normally a hot dry period and ideal for seed harvest. Our limited experience indicates that seed shattering is not as serious a problem with the phalaris synthetics as with reed canarygrass, agreeing with workers in England and Australia (16). However, McWilliam in Australia (12) has found a wide variation for seed retention among phalaris strains. The heritability coefficient was reported to be 0.92 ± 0.11 and was thought to be mainly due to additive gene action. Seed retention will need to be considered in a breeding program.

CONCLUSIONS

Phalaris tuberosa (*P. aquatica*) is a cool-season perennial grass species that merits consideration for breeding work in the South. Cultivars from Australia and California are not adapted, but the great diversity of germ plasm available in plant introductions suggests that cultivars can be bred for our region. The potential for high winter-forage production, cold tolerance, summer persistence, and high forage quality makes phalaris attractive. Some potential problems are nematode susceptibility, alkaloidal toxicity, and seed shattering. The progress that has been made to date in breeding and management studies encourages me to believe that phalaris may become a useful grass in the South.

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PROBLEMS ASSOCIATED WITH BREEDING FORAGE LEGUMES FOR RESISTANCE TO VIRUSES

By H. J. Walters [1/]

Plant breeders are aware of the difficulties in breeding forage crops. In his test "Breeding Field Crops," Poehlman lists 11 examples of these difficulties.[2/] Many of these could also be listed as problems encountered in breeding forage legumes for resistance virus diseases.

To begin with, most perennial legumes are cross-pollinated, which makes it difficult to propagate and maintain genetic identity of lines or clones. Diachun and Henson[3/] showed that a range of symptoms such as occurs in naturally infected fields of red clover can be induced by inoculation with one culture of bean yellow mosaic virus. Symptoms ranged from a mild mottle to lethal necrosis. A similar range of symptoms occurs in 'Ladino' clover infected with alfalfa mosaic virus. This range of symptoms emphasizes the difficulty of identifying viruses in clover by symptoms alone.

In addition to variation of symptoms in individual clones, a number of viruses infect forage legumes. Each virus usually has several strains which also complicates identification. Several viruses also have very similar symptoms when infecting legumes.

Identification of viruses affecting forage legumes can be done by host-range studies or by serological tests. Both of these methods present some difficulties. Serological tests are perhaps the best method, but most viruses affecting forage legumes are long, flexous rods for which good antiserum is difficult to obtain. Obtaining and maintaining good host material for identification of viruses is not always easy. Also, environmental conditions play an important role in symptom expression. Symptoms of several viruses affecting forage legumes are masked under high temperatures.

The presence of such diverse reactions or symptoms suggests the possibility of breeding resistant lines selected for immunity, a high degree of tolerance, or hypersensitive reaction. Immunity would be the easiest characteristic to test for, if immunity can be found, because plants would test out to be either susceptible or resistant. However, immunity might not be the most desirable type of resistance because it is easily broken down. A hypersensitive reaction would be relatively easy to handle and would lend itself well to mass testing.

A high degree of tolerance to disease would probably be the most desirable, but is most difficult to ascertain. We do not know which symptom denotes

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2/ Poehlman, J. M. 1959. Breeding field crops. 427 pp. Hold, Rinehart and Wilson, Inc., New York.

3/ Diachun, S., and Henson, L. 1974. Red clover clones with hypersensitive reaction to an isolate of bean yellow mosaic virus. Phytopathology 64: 161-162.

a high degree of tolerance. The determination of the effects of varied symptoms on yield, quality, and longevity would certainly be a difficult undertaking.

Although obtaining lines resistant to the various viruses affecting legumes is difficult, it is not an insurmountable problem. Given the equipment and manpower, it can be done.

PANEL ON VIRUSES AND FORAGES

By Will A. Cope [1/]

In a panel discussion during this conference, O. W. Barnett of Clemson University and others discussed the nature and extent of virus problems in farm crops as well as particular virus diseases and the extent of damage to specific crops. However, the actual damage to forage crops by virus diseases has not been fully evaluated and probably is not really known. We do know that white clover and red clover are subject to heavy damage by a number of virus diseases. Serious virus problems have also developed in certain of the forage grasses.

It is generally accepted that pests of a given crop increase somewhat in proportion to the amount of the crop grown in a given area and the number of years the crop is in production. Virus diseases appear to be an increasing part of the total plant-pest syndrome. This may result partly from a greater awareness of the effects of virus diease as specialists become more proficient in identifying viruses, the diseases they cause, and the damage that results. The overall significance of virus diseases may be brought into better perspective on consideration of the amount of work on viruses now being done by plant pathologists. A recent survey of a few issues of "Phytopathology" and "Plant Disease Reporter" revealed that approximately 20 percent of the articles reported work on plant viruses.

The panel members did a good job of providing information useful to the plant breeders who are involved with virus problems. These reports should also alert other breeders to the possibility of virus diseases becoming serious problems on other forage crops.

In summary, three general aspects of the problems involved in breeding for virus resistance should be pointed out.

(1) Host plants. Many different crop and weed species may be hosts of a particular virus, and the virus may not be named for its principal host. When alternate hosts are a reservoir for inoculation, breeding for resistance in the crop plant may be the only solution to the problem of continued crop production.

(2) Virus races. A given virus may have different forms or races that vary in virulence, thus creating the same kind of problem that we have in maintaining crop resistance to other pathogens in which genetically different races may develop.

(3) Inoculation. Mechanical or other efficient inoculation procedures have been developed for certain viruses. For others, no reliable inoculation techniques have yet been developed. In cases in which the breeder must depend on sporadic appearance of the natural insect vectors, progress in breeding for resistance can be slow and frustrating.

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VIRUSES AND VIRUS DISEASES OF SOUTHERN FORAGES
AND THEIR POTENTIAL EFFECTS

By R. W. Toler 1/

One of the principal forages in the South and Southwest is the sorghum-sudan hybrid. In recent years, the most serious disease problem has been maize dwarf mosaic caused by the maize dwarf mosaic virus (MDMV). Breeders have improved MDMV resistance in sorghum-sudan hybrids in the last few years by using 'Martin', and MDMV-tolerant variety, as the sorghum female parent. Sixty-five forage sorghums were evaluated for MDMV resistance under mechanical inoculation in 1973 in the Plant Sciences Department, Texas A & M University, at College Station. Forty-one rated tolerant, twenty-one intermediate, and four susceptible.

Millets are important forages inthe South and Southeast. A new disease, of St. Augustinegrass, names St. Augustin decline (SAD), caused by the St. Augustine decline strain of Panicum mosaic virus (PMV-SAD) has been reported in Texas, Louisiana, and Mexico. This disease attacks species of millet in the genera Panicum (proso), Setaria (foxtail) and Pennisetum (pearl).

The reaction of the proso millets to SAD vary from mosaic symptoms and death to resistance. The various degree of symptom expression also include mosaic and dieback, stunted blasted heads, stunted deformed heads, mosaics, and symptomless carriers. The susceptible millets such as 'Turgahi' are usually more lush in growth, while the resistant ones such as 'virgatum' are usually tougher plants with smaller leaves. Proso millet species found to be resistant are P. virgatum, P. amaralum, P. stapfianum, and P. miliaceum cultivars 'Leonard' and 'Early Fortune'.

Symptom expression in the foxtail millet species is a distinct pattern in all cases, followed by a reduction in head and leaf size and an overall stunted plant. The only differences noticed are in time to first seed head and time to symptom expression. All the foxtail millets tested were susceptible.

Reaction in the pearl millets varies from death of leaf tip to resistance. Symptom expression takes along time to occur, and it is always necessary to ressay on foxtail millet to be sure that the symptoms observed were due to SAD. Pearl millet cultivars found to be resistant were P. glaucum cultivars 'Gahi-1', 'Common', 'Tifton 239', and 'Tiftlate'.

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INCOMPATIBILITY SYSTEMS AND THEIR APPLICABILITY IN PRODUCING HYBRID FORAGES

By Melvern K. Anderson and Norman L. Taylor 1/

Self-Incompatibility

Self-incompatibility has been defined as the inability of a plant to set selfed seed and at the same time be cross-compatible. Self-incompatibility is very widespread and is estimated to occur in 3,000 species from 250 genera and approximately 70 families of plants (12, 35).2/ This inability to set selfed seed is severely detrimental to many breeding programs particularily for inbreeding and selection procedures. Conversely, self-incompatibility and cross-compatibility offer a mechanism of controlled pollination which can be exploited by plant breeders to produce hybrids. Hybrids take advantage of genetic potential and should be carefully considered in any breeding program. An excellent review of the evolution and mechanism of self-incompatibility was presented at the Southern Pasture and Forage Crop Improvement conference in 1969 by R. C. Leffel.

Incompatibility Systems

The main classifications of incompatibility systems are (i) the one-locus, multiple-allelic, gametophytic system; (ii) the two-locus, multiple-allelic, gametophytic system; (iii) the sporophytic-homomorphic system; and (iv) the sporophytic-hetermorphic system. Only the first three systems are used extensively in breeding cultivated crops. Accordingly, this paper will be confined to features involving these three types of incompatibility mechanisms.

The one-locus, multiple-allelic, gametophytic incompatibility system was discovered by East and Manglesdorf (23) in *Nicotiana*. It has since been found in many genera, including *Petunia*, *Lycopersicum*, *Solanum*, *Prunus*, and *Trifolium*. In essence, a pollen tube with an *S*-allele identical to one of the two *S*-alleles present in the stylar tissue will be rejected. Characteristically, this incompatibility system is strong at the diploid level and breaks down at the tetraploid level because of interactions or dominance between alleles in the pollen grain (12, 57).

The two-locus, multiple-allelic, gametophytic incompatibility system was

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first delineated by Lundquist (36, 37). In this system, which is found in certain grasses, the two loci are characteristically denoted as S and Z. Identity between pollen and pistil at neither or only one of the two loci alone gives a compatible reaction. Two related types of incompatibility were discovered by Pandy (53, 55). In a system in *Physalis*, the multiple-allelic S- and Z-loci show independent action or epistasis in such a way that the pollen may be incompatible even when only one of the alleles present in the pollen is present in the style. Another system in a Mexican species of *Solanum* carries two independent incompatibility loci, S and R. The S-locus is multiple allelic while the R-locus possesses only two known alleles. The genetic inheritance patterns are very complex and require intensive study.

The sporophytic-homomorphic system is a one-locus, multiple-allelic situation very similar to the one-locus gametophytic system previously described. This system is generally found in the Cruciferae and the Compositae. Again, genetic investigations can become very complex because of dominance or independent relationships. The first reports of sporophytic incompatibility were made by Hughes and Babcock (26) and Gerstel (24) in *Crepis foetida* and *Parthenium argentatum*, respectively. It appears to be more limited in occurrence than gametophytic incompatibility.

The application of a self-incompability system can result in controlled crossing for the production of a hybrid. This has long been recognized and has been pointed out by many investigators (4, 7, 8, 10, 13, 14, 19, 31, 32, 39, 41, 49, 51, 61, 62, 67, 68, 72). In essence, this method of producing hybrids is as follows:

(i) Production and selection of several inbred lines homozygous for different S-alleles.

(ii) Single-cross production between inbred lines (S_1S_1 X S_2S_2), (S_3S_3 X S_4S_4).

(iii) Double-cross production between single crosses (S_1S_2X S_3S_4).

Double-cross production is generally considered the most feasible because it provides an extra generation of seed production on vigorous plants in contrast to single-cross seed production from inbreds.

Many reviews have discussed various genetic aspects of incompatibility systems in detail (5, 37, 44, 45, 61, 71). Limiting our discussion, we will concentrate here on features that we feel are necessary for the production of hybrids using a self-incompatibility system. These features are the genetic control of crossing, the classification of S-genotypes, maintenance and increase of inbred lines, and the advantages of hybrid varieties over conventionally developed varieties.

The genetic control of crossing by the use of the self-incompatibility systems has been postulated since the early work of Rinke and Johnson (62) and Atwood (8). More recently, Nijenhuis (50) and Anderson et al. (4) used genetic markers to determine the extent of their control of crossing. Nijenhuis estimated the proportion of inbred seed in Brussels sprouts hybrid seed by acid phosphatase isoenzyme analysis and found up to 66 percent hybrid seed, as compared to estimates of up to 55 percent from field results. Using the leaf-marker gene and a white-flower marker gene, we found that control of crossing was almost complete, from 95 to 100 percent, in several clones of red clover and also in their inbred generations.

Understanding the classification of S-genotypes is estremely necessary if the breeder is to understand the segregation patterns in his populations. Leffel (31) studied the S-allele genotypes in the I_1 generation from I_0 red clover plants. He found no evidence for two classes of homozygotes

(S_1S_1 and S_2S_2) in small segregating populations. Johnston et al. (28) examined larger numbers of inbred populations of red clover and found two classes of S-homozygotes in two of three I_1 progenies. Generally, they found a deficiency in the pooled homozygous classes when compared to the heterozygous class. In one I_1 progeny they found only one class of S-homozygotes. Detection of S-genotype homozygotes in the sporophytic—homomorphic system is even more difficult because of dominance relationships and interactions among alleles (25).

Most S-genotype classifications are based on sib crosses in the greenhouse, and the number of crosses frequently is limited. Sib crosses in the greenhouse can be very time consuming and provide no information other than knowledge of S-genotypes. It would be desirable to obtain agronomic information about inbred progenies and at the same time classify S-genotypes. Determining both of these factors simultaneously should expedite the recovery of superior homozygous S-genotype plants for use in a breeding program. We have made vegetative increases of I_1 clones and isolated I_1 progenies under caged field conditions. In most cases, we were able to accurately classify S-phenotype under field conditions by examining seed set (heterozygous, no seed set: homozygous, seed set). Selections for agronomic types and S-homozygotes can be done simultaneously, saving time. Obviously, the more quickly that S-genotypes can be classified, the more rapidly progress can be made.

Biochemical determinations of S-genotypes have had varying degrees of success. Nasrallah et al. (43) accurately determined S-genotypes by applying disc electrophoresis methods to stigmatic homogenates. Preliminary attempts to classify S-genotypes from vegetative tissue by Bredemijer (11) were also promising. We (1) attempted to determine S-genotypes in red clover leaves by chemical characterization of caffeic acid, kampferol, peroxidase, and polyphenol oxidase. We found significant differences in some progenies but not enough variation to be of any practical benefit. Ideally, as tissue culture methods become more refined, haploid procedures as outlined by Collins and Legg (17) will be of obvious value for the production of S-genotype homozygotes.

The increase and maintenance of inbred lines is extremely important and has been the subject of many investigations (8, 10, 62, 72). These workers and others have pointed out that inbred clones or lines can be used with the control of crossing by the incompatibility system in the production of hybrids.

A major obstacle to implementing the incompatibility system for hybrid production is the difficulty of inbred line increase. Many investigators have studied pseudo-self-compatibility (PSC) in cultivated crops, as pointed out by Townsend (71).

It has been estimated that incompatibility can be influenced by over 30 different factors. Leffel (31) made a major breakthrough when he used high temperature treatment, which reduced the strength of the incompatibility reaction, to produce large quantities of selfed seed in usually self-incompatible clones of red clover. Various techniques and treatments are available for the temporary breakdown of the self-incompatibility reaction. Among the most notable of these are bud pollination (33, 54); delayed self-pollination (6, 29); grafting (20); heat treatments (30, 31, 46, 70); carbon dioxide application (42); hormones and protein inhibitors (18, 38, 46, 57); irradiation (33, 47); mulilation (63); and electric shock (64).

Once he finds a suitable method for overcoming self-incompatibility, the breeder faces determining PSC levels in his material. Some degree of PSC must be under genetic control to use seed maintenance and increase schemes. Leffel (31) found that PSC was a clonal characteristic which interacts significantly with temperature. Subsequent studies by several investigators (30, 46, 70)

also showed increases in percentages of selfed seed produced at higher temperatures. Many investigations have shown PSC to decrease with inbreeding at normal or higher growing temperatures (20, 21, 40, 67, 69).

Generally, three methods of increase or maintenance of inbred lines are available, depending upon the species involved. These are vegetative maintenance, seed maintenance via PSC, and a combination of seed and vegetative maintenance. Special interest has been focused on increasing and maintaining inbred lines of red clover in the last several years. According to Leffel and Muntjan (32), a seed-maintenance scheme could use PSC and high temperature to self I_0 plants and for alternate generations of sib mating when the population is composed of uniformly heterozygous *S*-genotypes. They stated that sib mating in the I_1 generation and in alternate subsequent generations would occur under normal conditions because of three different *S*-genotypes in each population. This method would lead to a single-cross rather than a double-cross hybrid because the inbred lines would be heterozygous for *S*-genotypes in the final stage of increase.

The method outlined by Taylor et al. (67) involved selfing I_0 clones under field conditions to obtain I_1 plants possessing homozygous *S*-genotypes. Four selected I_1 plants with homozygous *S*-allele genotypes would then be vegetatively increased. Two single-crosses could be made from combining two sets of vegetatively increased I_1 lines. The single-cross seed could then be blended for the production of a double-cross hybrid red clover.

To maintain inbred lines by seed maintenance, a heritable level of PSC (8 to 10-percent) is necessary to produce sufficient seed. However, more than 10-percent PSC would probably allow sib mating and selfing to occur, and a true hybrid would not be formed. We have found several lines with PSC values of around 10-percent which could possibly be used in the maintenance program (21). However, increasing these lines would be progressively difficult because PSC declines with inbreeding, and, even with a field increase program, only a very small amout of seed could be produced. Even if clones showing high PSC in the I_1 generations were selected, only a few would give progeny with high PSC. In our results, one line having PSC levels that approached those of their respective parents was found within each clone. The generations nearest their respective parents had the highest PSC levels, and pooled means for each clone which estimated the PSC levels of its parents were much lower than the actual levels. Since only a few lines possessed a 'desirable' degree of essential PSC, selection of inbred lines would perhaps have to be based on PSC rather than agronomic type. If restrictions such as these are placed on the breeder from the very first step of breeding, it is doubtful that strict seed maintenance of inbreds is practical.

Because of the difficulties in finding I_2 lines with about 10-percent PSC, we proposed a scheme of maintenance and increase of inbred lines which combines the most desirable features of both seed and vegetative maintenance systems (21). Superior I_1 plants with different but homozygous *S*-genotypes and a high degree of PSC (8 to 10 percent) would be vegetatively increased. These I_1 lines would then be isolated under high-temperature field conditions, and selfed seed would produce the I_2's. The selfed seed from the I_1's (I_2) would then be mixed and sown to produce single-cross seed. Single-cross seed from different clonal sources would be mixed and sown to produce double-cross hybrid red clover. The advantages of this inbred line maintenance scheme are (i) a double-cross hybrid could be produced instead of a single-cross hybrid; (ii) an extra generation of increase would be added to the vegetative maintenance scheme; (iii) PSC could be used when at the highest practical level; and (iv)

the time needed to produce a hybrid could be reduced in comparison with the other two methods. Actual estimates of PSC in inbred lines under high-temperature field conditions are necessary before final conclusions can be made.

In order to maintain effective genetic control of crossing, S-allele stability during inbreeding is necessary. Bateman (9) and Williams (73) have determined that the number of multiple alleles present at the incompatibility locus is very high. Concurrent with these investigations have been numerous unsuccessful attempts to induce constructive or positive mutations at the S-locus (34, 52, 56).

Recent evidence suggests that inbreeding is responsible for the generation of new S-alleles (2, 3, 20, 44, 48, 59). The exact mechanism which generates S-alleles during inbreeding is unknown, but possibilities, including mutation, intracistronic recombination by deletions, duplications, substitutions; equal or nonequal crossing-over; mutation by activation-inactivation phenomena; and homozygosity influences on recombination have been proposed (44, 48, 58-60).

A major difference between de Nettancourt et al.'s S_3 allele in *Lycopersicum* (48) and our S_{17} allele in *Trifolium* (2) is that their allele was recovered in "large waves and high frequencies" while ours was only recovered once. Our results may be more easily explained if these hypothetical mechanisms prove to be true, whereas de Nettancourt's (48) are more likely if, as they suggest, some inactivation-activation phenomena is involved. However, the results of our tests with a large amount of genetic material seem to make their explanation less likely.

Changes in S-specificity would seriously affect the maintenance and increase of inbred lines by successive seed generations. Continued seed maintenance by PSC and sib mating in alternate generations may induce new S-specificities because of inbreeding. Thus, two isolated inbreds would sib mate as well as cross and a true single-cross would not be formed. The effect of a change in S-specificity would be minimized by the scheme we have suggested in Duncan et al. (21). This combined system of maintaining inbred lines would use selfing by PSC for only one generation. Therefore, if new S-specificities did occur, they would not have an opportunity to increase enough in a population to cause any appreciable intraline crossing.

The advantages of hybrid varieties are very important in considering possible routes to variety development. Several of the advantages of hybrid varieties can be grouped under the following discussion. Inbreeding depression is a general feature associated with most cross-fertilizing species, Busbice et al., (16) reported inbreeding coefficients in alfalfa, ranging from 0.009 to 0.518, from various research results. Taylor et al. (67) measured inbreeding depression in I_0 and I_1 generations of red clover. Significant heterotic responses have been reported in several crops (65) and are generally widespread enough to justify hybrids.

Uniformity of the harvested product is critical in such crops as Brussel sprouts (27). Most varieties have been produced by selection and mass pollination and often show considerable intravarietal variability. The uniformity produced from hybrids may in itself be enough justification for their production.

Hybrids can also give maximum flexibility. For example, many varieties of sweet corn and tomatoes introduced into Hawaii from the mainland will do poorly. However, hybrids produced from temperate inbreds and tropical inbreds will have a much wider range of environments in which they will thrive (22).

Synthetic varieties are subject to genetic shifts which result from many causes during generations of seed increase. Taylor et al. (66) discussed some of the factors that are important causes of shifts in red clover. Also, the inbreeding that develops during seed increase usually results in a decrease in performance of synthetic varieties (15). Therefore, a self-incompatibility system would permit the production of non-inbred cultivars with only four parents and insure that only certain types of matings occurred during seed production and thus may also be useful in the prevention of genetic shifts.

CONCLUSIONS

In conclusion, we feel that incompatibility systems are widespread in many of the open-pollinated forage grasses and legumes and can be exploited for hybrid production. Admittedly, the system has problems, but if maximum genetic gains are to be accomplished we must undertake to overcome or circumvent these problems. Other methods such as the cytoplasmic-sterility/fertility-restoration system have had difficulties which have been mostly overcome. Incompatibility systems offer controlled pollinations without backcrossing into exotic cytoplasms which many times have adverse effects. Also, pollen production is normal with these systems, which may be a great advantage in crops like alfalfa and red clover which rely heavily on bees for cross-pollination.

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A SURVEY OF FORAGE CROP VIRUS DISEASES

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INTRODUCTION

As forage breeders you are interested in improving the quality and quantity of legume or grass production. Most of the characteristics for which you are trying to breed or select are probably agronomic in nature. With the release of better varieties, which are usually grown as monocultures, and with the acceptance of better management practices, diseases become a limiting factor. Many of you, either independently or in cooperation with a pathologist, are trying to incorporate disease resistance into the crop you are interested in. Very few pathologists are working with diseases of forages and there are only 12 projects listed with Current Research Information Systems (CRIS) dealing with virus diseases of forages, 8 on legumes and 4 on grasses.

I wish to acquaint you with some of the known viruses which infect forage grasses and legumes and to point out some of the effects of virus diseases on forage crops.

Viruses may be present but not recognized, or the effects of viruses may be confused with other problems. Symptoms can vary from plant to plant and with the environment. Accurate identification requires time and the use of techniques which may not be available to breeders. A comprehensive study of the virus diseases in a crop may add to the list of recognized viruses. For example, in 1968, 11 grass viruses had been found in Wales (1). By 1971, 16 grass viruses were known, so obviously more viruses will be described as research efforts continue(4).

Table 1 and 2 contain a partial list of viruses which infect forage crops, some of their characteristics, distribution, general symptoms, and some of the main host plants. Some terms used in the tables need to be defined. Stylet-borne transmission means that the vector acquires the virus and inoculates a healthy plant with the virus in short exploratory probes. The vectors retain the ability to transmit for only a few hours. Viruses transmitted in a circulative manner are picked up and inoculated by the vector after longer feeding probes. The vectors retain the ability to transmit for several days, sometime for the life of the vector. The virus is carried inside the vector's body, can be detected in the haemolymph, and some viruses are actually propagated in the vector. Virus-vector relationships are very specific even in stylet-borne transmission.

Virus particles can be seen with an electron microscope. Size and shape of the virus particles differ among the viruses. The morphological characteristics can be used with other characteristics for identification and grouping. Many of the viruses, such as peanut stunt virus, are spherical. Others, such as clover yellow vein virus (CYVV), are rod-shaped. Some viruses are bacilli-

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form, for example alfalfa mosaic virus (AMV), or maize mosaic virus which has a complex structure much like the animal virus, vesicular stomatitis.

It is impossible to discuss all of the viruses which affect forages in this limited space. Some of the more imporatant viruses of forage crops are discussed in this paper but all viruses affecting forage crops are not covered.

Viruses of Grasses

Cocksfoot streak virus (CSV) was the first grass virus reported in Britain (1). Orchardgrass mosaic reported from the United States may be the same virus, but, unlike CSV, it infects oats. CSV does not cause stunting but reduces tiller production up to 40 percent (5). Flowering tiller production is not affected, but seed setting is reduced slightly. This virus is common in seed crops but rare in pastures because the infected plant is eliminated by competition where frequent defoliation occurs (6).

Maize dwarf mosaic virus, first described in 1965, causes mosaic and slight stunting on corn (13). Some strains overwinter in johnsongrass. Severe stunting and chlorosis occur when certain forage sorghum varieties are infected.

Barley yellow dwarf virus (BYDV) causes epidemics in oats and barley. In barley, the leaves turn yellow, while in oats the main symptom is leaf reddening. A survey in England and Wales revealed that 93 percent of perennial ryegrass seed stands were infected with BYDV (12). Fescue infected with BYDV may develop yellow leaves (22). BYDV reduced the yields of single spaced plants of Italian ryegrass, perennial ryegrass, tall fescue, and Timothy by 45, 63, 71 and 72 percent respectively, in tests conducted in Wales (4). Tillering is not reduced by BYDV but plant height is generally reduced (3). Because of these effects, BYDV competes well in a pasture situation and there is no compensation by the surrounding plants for the loss of yield due to height reduction. Since the infected plants spread more rapidly than healthy ones, the production of the sward declines continuously.

Ryegrass mosaic virus (RMV) is the most widespread mechanically transmissible virus affecting Gramineae in Britain where it is common in ryegrass seed crops and permanent pastures (4). Like CSV, it reduces tillering but not plant height so neighboring plants compensate. A combination of BYDV and RMV greatly reduces the productivity and lengevity of ryegrass.

Maize rough dwarf virus occurs only in Europe and the Middle East. According to Klein (11), bermudagrass is a perennial host for this virus. Only after bermudagrass is infected with the virus is the grass also a host for the leafhopper vector of this virus.

Panicum mosaic virus was reported by Sill in 1975 (20). In 1967, McCoy et al. (19) found a mosaic disease of St. Augustine grass. A light mottling first occurs on St. Augustine grass, followed by general chlorosis, shortening of the internodes, necrosis, and general decline of the lawn. Lawns in Texas vary from a trace to 100% infected. Millet can be experimentally infected (19). Panicum mosaic and St. Augustine decline viruses are serologically related (18).

Viruses of Forage Legumes

Alfalfa mosaic virus (AMV) has a wide host range, mostly in the dicots, and is distributed worldwide. In Wisconsin 55 percent of the plants sampled were infected, while in some 2-year-old stands, 89 percent of the plants were infected (8). In Britain AMV was found in alfalfa and red clover but not in white clover even though the aphid vectors were prevalent (2). It commonly

occurs in white clover in the United States.

Bean yellow mosaic virus (BYMV) is the most prevalent virus of red clover (9). CYVV occurs in most white clover pastures in the southeastern states and was probably mistaken for BYMV in many publications. Extensive surveys of the southeastern states and of Britain (14) did not detect BYMV in white clover, and BYMV did not infect white clover after mechanical inoculations. BYMV and CYVV can be easily confused unless serological test methods are used.

Peanut stunt virus (PSV) was also detected in most white clover fields. This virus can cause severe stunting of white clover. AMV, CYVV, and PSV are the three most prevalent viruses in white clover. All three are aphid transmitted.

White clover mosaic virus (WCMV) occurs in white clover over much of the United States but a similar virus, clover yellow mosaic virus, occurs mostly on the west coast. WCMV occurred in 30 percent of the pastures sampled in the Southeast; usually a low percentage of the clover plants in the pastures were infected. No vector is known for either WCMV or CYMV.

Some of the nematode transmitted viruses, such as arabis mosaic, strawberry latent ringspot, tomato black ring, and tobacco rattle can infect both the grasses and legumes in a sward (4). These viruses are not common in the United States, but tobacco ringspot virus (TRSV) does occur commonly in the United States, and has hosts in the monocots as well as dicots. Corn is a host of TRSV but few host range experiments have been done with grasses. The vector, *Xiphinema americanum*, is commonly found in pastures.

Effects of Viruses on Plant Growth

The effects of virus infection on forage legumes or grasses has not been extensively studied. Much of the information was taken from monocultures which would not be appropriate for most pasture situations. Most of the viruses which infect forages are restricted to either the grass or the legume component. The few viruses which infect both grasses and legumes have not been extensively studied in pasture situations.

A combination of viruses (probably CYVV and AMV) in white clover reduced yields from 23 to 55 percent in pure stands under greenhouse or field conditions (17). Flowering was reduced 20 to 44 percent and seed yield 29 to 54 percent (16). BYMV infection of red clover reduced shoot height, dry matter per plant, digestible dry matter per plant, total nitrogen per plant, percent dry matter in the stem, and chlorophyll concentration (21).

Much of the relevent work on effects of grass viruses has come from the Welsh Plant Breeding Station (1). CSV, RMV, and BYDV reduce the yield of single spaced plants by at least 20 percent. However, the viruses cause different effects on plant growth habit and yield reduction in a sward which is not 100 percent infected. BYDV reduces the height of its grass hosts but may increase the number of vegetative tillers. CSV and RMV, however, have little effect on plant height but reduce the number of vegetative tillers. Thus, BYDV causes the largest yield losses with occasional defoliation such as would occur in a hay crop, but CSV causes largest losses with frequent defoliation.

Yield losses would be hard to study under natural conditions where both viruses might be present together. By using simulated swards with known levels of virus infection, the effects of virus-induced plant behavior on yield can be seen (3, 6). Swards which were 100 percent CSV-infected and which were frequently defoliated, had a yield half that of healthy swards. When only half the plants were infected no yield reduction occurred. In swards which were

100 percent infected with BYDV, yield was reduced to 70 percent of the healthy swards and even in swards which were only 50 percent infected, the yield was still only 75 percent of the healthy swards.

The differences in the two swards in which half of the plants were infected resulted from the different ways the two viruses affected plant growth (Fig. 1). Healthy plants filled in the space lost by reduced tillering in plants infected with CSV but no compensation occurred in the sward infected with BYDV where plant height but not tillering was reduced.

Virus infection can also influence the composition of the sward. In white clover-ryegrass swards, BYDV infection of the ryegrass tends to favor the clover component (3). In mixed swards, CSV reduces the survival of orchardgrass. The lateral expansion of the legume component as it takes over the areas previously occupied by infected orchardgrass results in a change in the relative proportion of species in the sward (6).

Breeding for Virus Resistance

Plant breeding offers the best prospect for the reduction of forage yield losses due to viruses, primarily because chemical control of vectors is expensive and has not been very effective in controlling most virus diseases. Resistance to BYMV and red clover vein mosaic virus in red clover is under study in Kentucky and Wisconsin. BYMV resistance in red clover was controlled by a single dominant factor, and several homozygous inbred clones from normally self-incompatible plants were obtained by selfing flower heads at high temperature (35-40^{o}C) while the rest of the plant remained at a lower temperature (10). Some problems have been encountered with incorporation of this resistance into the clones of 'Kenstar'. Some of the clones of 'Kenstar' apparently carry a partial resistance that prevents the expression of the hypersensitive type of resistance (Diachun, personal communication).

A problem very similar to that of the BYMV resistance in red clover was encountered by the Welsh workers with BYDV resistance in barley (7, 15). A gene for tolerance to BYDV was found in rapidly maturing Ethiopian barley. Incorporation of this tolerance into slow growing European cultivars was found to be complicated; the effectiveness of the tolerance required rapid growth. This reduction of tolerance occurred when growth conditions of the Ethiopian lines were changed or when the gene was incorporated into slower growing European type lines. This modifying factor will have to be overcome before barley varieties tolerant to BYDV can be produced with this Ethiopian barley as the source of tolerance.

The inheritance of MDMV resistance presents another difficulty encountered in breeding for virus resistance. Genter et al. (13) found that resistance from one corn line was dominant but intermediate resistance in two other corn lines was recessive to susceptibility.

S. C. Schank at the University of Florida, Gainesville, has screened for resistance to Pangola stunt virus in Digitaria species hybrids by sending them to Guyana or Surinam (from the 1973 CRIS report). This type of screening might be useful where a variety should be adaptable in more than one country. However, field screening may be complicated if more than one virus infects the crop under natural conditions. Working with a single virus strain may simplify studies on virus resistance. For instance, four strains of BYMV gave different reactions on various red clover clones but only one strain was used in the red clover breeding program because it was most prevalent (9, 10).

DISCUSSION

From this discussion, I hope you realize that there are many viruses which infect both the grass and legume forage crops. Many times, identification of these viruses is difficult, but it is essential to know exactly which virus is involved prior to initiating a breeding program. Viruses may reduce yield significantly under some management practices but not under others, and in general, as better management practices are followed, the importance of reduced yield dut to virus infection increases. As breeding programs for virus resistance are started, an initial study of the viruses and the virus strains involved as well as of the inheritance of resistance whould make obtaining the resistant variety easier in the end.

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TABLE 1.--Viruses of grasses[1/]

Virus	Morphology	Georgraphical distribution	Symptoms	Hosts
Aphid-transmitted, stylet-borne:				
Cocksfoot streak virus	750 nm rod	Britain, Europe	Mild or severe streak, decreases tillering	Orchardgrass, ryegrass
Orchardgrass mosaic	Unknown	United States	Blue-green dwarfing	Orchardgrass, oats
Maize dwarf mosaic virus	750 nm rod	United States, Europe	Mosaic	Corn, johnsongrass, sorghum
Aphid-transmitted, circulative:				
Barley yellow dwarf virus	25 nm sphere	Worldwide	Yellowing, reddening, stunting, sterility	Over 100 grasses, including wheat, barley, oats, fescue, ryegrass
Beetle-transmitted:				
Brome mosaic virus (reported Nematode transmissions)	25 nm sphere	United States, Europe	Mild mosaic	60 grasses, brome, reygrass, corn
Cocksfoot mild mosaic virus (poorly transmitted by aphids, serologically related to phleum mottle below)	30 nm sphere	England	Yellow and brown	Orchardgrass, wheat, oats
Lolium mottle virus (transmission not shown)	30 nm sphere	England	Mottle and general yellowing	Ryegrass
Phleum mottle virus	30 nm sphere	England	Pale mottle	Timothy and bents

TABLE 1.--Continued

Virus	Morphology	Geographical distribution	Symptoms	Hosts
Mite-transmitted:				
Agropyron mosaic virus	720 nm rod	United States, Canada, Finland,	Light green or yellow mosaic	Quackgrass, wheat
Ryegrass mosaic virus	700 nm rod	United States, Canada	Yellowish mottle streaks	Ryegrass, fescue, oats, orchardgrass
Wheat streak mosaic virus	700 nm rod	United States, Canada, Europe	Severe mosaic, stunting, reduced seed-set	Wheat, oats, rye, barley, many wild grasses
Leafhopper-and planthopper-transmitted:				
Maize mosaic virus	Bacilliform	Caribbeans, Venezuela, Puerto Rico, Hawaii	Yellow spots and stripes, stunting	Corn, sorghum, millet
Maize rough dwarf virus	70 nm sphere	Europe, Middle East	Dwarfing, enations	Corn, bermudagrass, barnyard grass, crabgrass
Oat blue dwarf virus	30 nm sphere	United States, Canada	Blue-green foliage, stunting, leaf and stem enations, sterile florets	Oats, barley
Wheat (American) striate mosaic virus	Bacilliform	United States, Canada	Striate mosaic	Stinkgrass, witchgrass, wheat, oats
Fungus-transmitted:				
Oat mosaic virus (vector not identified)	700 nm rod	United States, England, New Zealand	Mild mosaic	Oats, wheat
Wheat soil-borne mosaic virus	150 nm rod	United States, Japan, Italy	Green to yellow mosaic	Wheat, barley, brome

TABLE 1.--Continued

Virus	Morphology	Geographical distribution	Symptoms	Hosts
Nematode-transmitted:				
Lolium latent virus (probable)	25 nm sphere	England	None obvious	Ryegrass
Seed-borne transmission:				
Baley stripe mosaic virus	130 nm rod	Worldwide	Mild mosaic to severe necrosis	Wheat, barley
Vector not known:				
Foxtail mosaic virus	Unknown	United States	None or chlorotic spots and stripes	45 grasses, 30 dicots, wheat, barley, foxtail,
Panicum mosaic virus	25 nm sphere	United States	Yellow-green mosaic, stunting	Switchgrass
St. Augustine decline strain	25 nm sphere	United States	Mosaic, stunting	St. Augustine grass, millet

1/ Information from references in "Literature Cited" at the end of this paper or from the series Descriptions of Plant Viruses, B. D. Harrison and A. F. Murant (eds.), Commonwealth Mycological Institute and Association of Applied Biologists, Farnham Royal, Slough, England.

TABLE 2.--Viruses of forage legumes[1/]

Virus	Morphology	Geographical distribution	Symptoms	Hosts
Aphid-transmitted, stylet-borne:				
Alfalfa mosaic virus	Bacilliform	Worldwide	Mosaic or necrosis	Red, white, and crimson clovers, alfalfa
Bean yellow mosaic virus	750 nm rod	Worldwide	Mosaic	Red and crimson clovers
Clover yellow vein virus	750 nm rod	United States, Canada, Britain	Mosaic or none	Alsike, red, and white clovers
Pea mosaic virus	750 nm rod	Worldwide	Mosaic	Red clover
Pea streak virus	630 nm rod	United States, Germany	Mosaic or none	Red and white clover
Red clover vein mosaic virus	670 nm rod	United States, Canada	Mosaic, streaking, stunting	Alsike, red and white clovers
Peanut stunt virus	30 nm sphere	United States	Mosaic, stunting	White clover
Aphid-transmitted, circulative:				
Bean leaf roll virus	Unknown	Europe	Vein yellowing	Red and white clovers, alfalfa
Subterranean clover stunt virus	Unknown	Australia	Stunting, cupping of leaves, reddening	Subterranean and white clovers
Pea enation mosaic virus	30 nm sphere	Worldwide	Mosaic, enations	Crimson and white clovers, alfalfa
Nematode transmitted:				
Arabis mosaic virus	30 nm sphere	Europe	Faint mottle or none	Red and white clovers, bluegrass

TABLE 2.--Continued

Virus	Morphology	Geographical distribution	Symptoms	Hosts
Tobacco ringspot virus	30 nm sphere	United States, Canada	Mottling	White clover
Pea early browning virus	210 nm rod	Europe	Mottling, striping	Red and white clovers, alfalfa
Vectors not known:				
Red clover mottle (serologically related to beetle transmitted viruses)	30 nm sphere	Europe	Mottle	Red clover
Clover yellow mosaic virus	540 nm rod	United States, Canada	Green to yellow striping, reduces winter hardiness	Red and white clovers, alfalfa
White clover mosaic virus	480 nm rod	United States, Canada, Europe	Mosaic, mottle or none	Alsike, crimson, red and white clovers, alfalfa

1/ Information from references in "Literature Cited" at the end of this paper or from the series Descriptions of Plant Viruses, B. D. Harrison and A. F. Murant (eds.), Commonwealth Mycological Institute and Association of Applied Biologists, Farnham Royal, Slough, England.

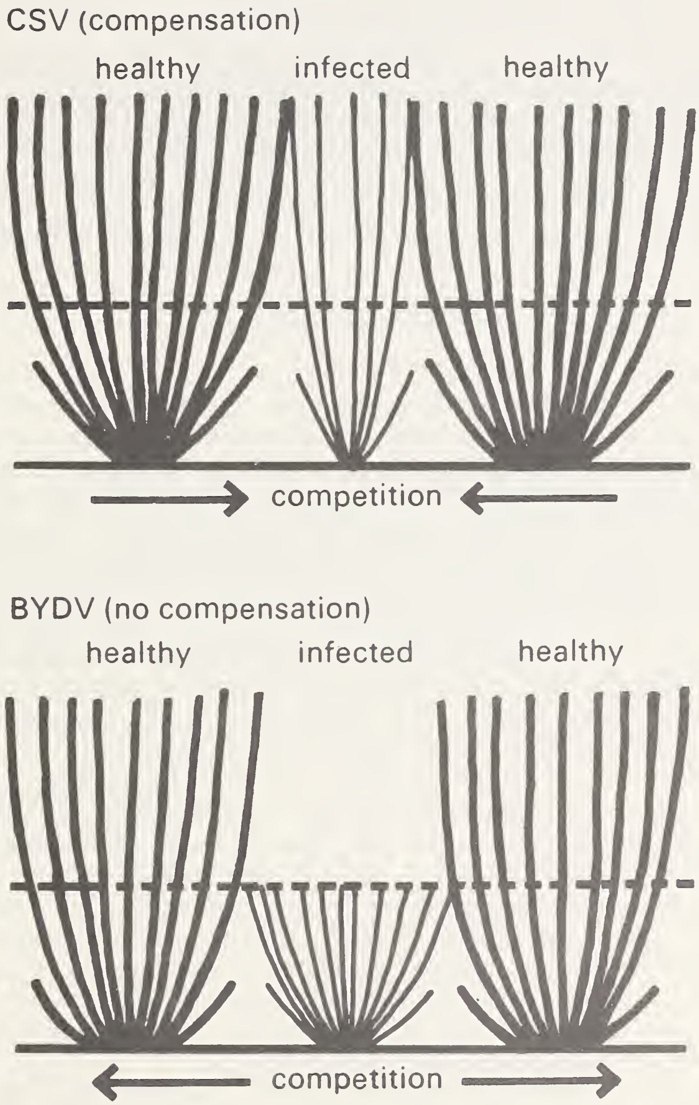

Figure 1.--Different effects of cocksfoot streak virus and barley yellow dwarf virus on plant growth habits. (Appreciation is expressed to A. J. H. Carr and P. L. Catherall for permission to publish this figure which appeared in Span 11(1968 : 92-95.)

EXPLORING FOR FORAGE LEGUMES IN THE WESTERN MEDITERRANEAN

By Ian Forbes, Jr. [1/]

In the spring of 1973, J. S. Gladstones (Senior Plant Breeder, Western Australia Department of Agriculture) and I conducted a search for wild ecotypes of forage legume species that were of special interest for our respective breeding programs in Western Australia and southeastern United States. The countries explored were Morocco, Tunisia, Spain, and Portugal. I was invited to present this report on the methods and results of the expedition to the United States' 31st Southern Pasture and Forage Crop Improvement Conference.

Target Species

It is essential to the success of plant exploration to have a fairly restricted objective in terms of the genera or species selected for seed collections. Otherwise, time limitations can prevent comprehensive collections of the major target species. Gladstones and I have cooperated for a number of years on a *Lupinus angustifolius* L. (blue lupine) improvement program, and Gladstones has also been breeding *Lupinus cosentini* Guss. (Western Australia blue lupine). In *L. angustifolius*, we were particularly interested in ecotypes with brownspot resistance, good seed-setting under hot conditions, and greater winter hardiness. This species is showing potential as a high-protein feed-grain crop for use in poultry and pig rations in Western Australia. In the United States it has been used as a late winter-early spring temporary pasture and as a green-manure cover crop. Its potential in the United States as a high-protein feed grain is under preliminary investigation.

We are both involved in breeding programs with *Trifolium subterraneum* L. (subterranean clover) for use as a reseeding winter-spring pasture crop. Much of the germplasm previously available has been naturalized strains of Australian and not of Mediterranean origin. Gladstones has been involved in *Ornithopus compressus* L. (yellow-flowered serradella) breeding, and this species may have potential as a reseeding winter annual pasture crop on deep, acid sands in the southeastern United States. *Medicago truncatula* Gaertn. (barrel medic) has become an important pasture plant in Western Australia on heavy, neutral to alkaline soils and may find a place in such soils in the southern United States. Biotypes with non-spiny seed burs were sought.

These species, all reseeding winter annuals in the wild, were the major target species. Some closely related species were also collected.

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General Procedures

In order to follow the season of seed maturation of the target species, the sequence of the countries explored was Morocco, Tunisia, Spain, and Portugal. Upon arrival in each country, we spent 1 or more days, depending upon the country, meeting prearranged contacts for orientation, obtaining additional maps and supplies, visiting herbaria, and renting a vehicle. Travel within each country was by rented automobile. No guides or interpreters were used. Our profiency in the French and Spanish languages was adequate on most occasions.

Using maps to plan the itinerary within each country, we chose centrally located towns or cities in each region as bases from which to explore the countryside for 1 or more days. We identified the location of each seed-collection site by map reference; i.e., distance and direction along roads from towns or cities. At each collection site we recorded the collection number, species collected, location, altitude, soil type, pH of soil, grazing intensity, etc. We used an air-pressure altimeter and a soil pH test kit to measure altitude and soil pH, respectively. Seeds were dried as quickly as possible after collection and field dressed or threshed as the species warranted.

Morocco

After meeting in Lisbon, Portugal, we flew to Casablanca, Morocco, rented a vehicle and drove to the capital, Rabat. We visited with the U.S. Agricultural Attache, with the Agricultural Scientists of the United States Agency for International Development mission, and at the Mohammed V University. Through these sources we became well-oriented, obtained maps, and were given an opportunity to visit the University's herbarium.

As temporary bases of operation, we used in sequence Rabat, Agadir, Marrakech, Azrou, Al Hoceima, Chechaouene, and Tangier. Communication with the Moroccans was in French, Spanish, English, sign language, and pictographs. The peoples we contacted were ethnically varied, and cultures varied from modern in large cities to ancient in relatively isolated regions.

Generally, Morocco had a dense population of sheep, goats, cattle, camels, horses, donkeys, etc., and because of less than usual rainfall, pastures were grazed very short. This made location and collection of seed of grazed species more time-consuming. Moroccan boys, who appeared on the scene at nearly every collection site, frequently assisted in seed collection. We made 133 seed collections in Morocco (table 1). A few *Rhizobium* nodules were collected from *L. angustifolius*. We ended our collection circuit of Morocco in Rabat and sent the seed via United States diplomatic pouch to the United States' Plant Inspection Station with instructions to forward Gladstones' share of each collection to Australia.

Tunisia

We flew from Casablanca via Algiers to Tunis, Tunisia. John B. Doulette, CIMMYT, Tunis, an acquaintance of Gladstones', was very helpful in orienting us and in procuring road and pedological maps. He accompanied us on the exploration of the Cap Bon Peninsula. Communication with Tunisians was in French, English, sign language, and pictographs. Although the grazing animal species were much the same as those encountered in Morocco, the animal population was

not as dense. It was interesting to note in both countries the absence of barbed wire to control grazing. Herdsmen, mostly young boys, controlled the animals.

TABLE 1.--Forage legume seed collections made in western Mediterranean countries, May-June 1973

Species collected	No. of seed collections made in				Total
	Morocco	Tunisia	Spain	Portugal	
Lupinus albus L.	1	2	---	---	3
Lupinus angustifolius L.	21	---	88	15	124
Lupinus atlanticus Gladstones	6	---	---	---	6
Lupinus cosentini Guss.	14	5	1	---	20
Lupinus hispanicus Bois. & Reut.	---	---	25	11	36
Lupinus luteus L.	---	---	2	2	4
Lupinus micranthus Guss.	1	---	---	---	1
Medicago littoralis Rhode ex Loisel.	7	2	---	---	9
Medicago orbicularis (L.) Bart	3	3	---	---	6
Medicago tornata (L.) Mill.	16	4	2	---	22
Medicago truncatula Gaertn.	10	---	---	---	10
Other Medicago spp.	2	4	---	---	6
Ornithopus compressus L.	24	7	47	11	89
Ornithopus isthmocarpus Coss.	4	---	---	---	4
Ornithopus perpusillus L.	1	---	1	---	2
Ornithopus pinnatus (Mill.) Druse	2	3	8	4	17
Trifolium repens L.	1	---	6	---	7
Trifolium subterraneum L.	19	21	14	5	59
Trifolium subterraneum L. var. brachycalcinum Katz. and Mor.	1	4	---	---	5
Total	133	55	194	48	430

Our exploration was confined to the northern part of Tunisia, as far south as Sousse. Aside from Tunis, bases of operation here were Sousse, Le Kef, Ain Draham, and Tabarka. The Ain Draham-Tabarka area was particularly productive of Trifolium subterranneum seed collections. In this region, we followed the Tunisian-Algerian border for some distance, but did not enter Algeria. We found no Lupinus angustifolius in Tunisia, but we made several collections of L. cosentini, one in the coastal sand dunes at Sousse. We collected Rhizobium nodules from the plants at Sousse since they were so far removed geographically from the other Lupinus sp. from which we had collected nodules in Morocco.

Many Tunisian boys helped us in collecting seeds. We made 55 seed collections in Tunisia (table 1). On our return to Tunis, the seeds were packaged and sent off by United States diplomatic pouch as had been done in Morocco.

Spain and Portugal

We flew from Tunis via Rome to Madrid, Spain. Through the U.S. Agricultural Attache in Madrid it was possible to locate soil, rainfall, and temperature maps for Spain. Because of the size of the area to be explored and differences in the L. angustifolius ecotypes we hoped to find, we rented two vehicles and divided the area to be explored between us.

I explored from Madrid to the northeast through Zargoza as far as Barcelona; westward in the Pyrennes Mountains to San Sebastian; westward to Oviedo; the Cantabrica Mountains; and northeast of Segovia to Soria. Gladstones explored northwest of Madrid to Segovia; west to Ciudad Rodrigo; most of southwestern Spain; Portugal from Evora in the south; northward across the northern Portugal border to Monforte, Spain; and then south to Lisbon. I flew from Madrid to the United States bringing the Spanish seed collection with me under seal and forwarded Gladstones' share of the seed by airmail. Gladstones sent a share of the seeds he had collected to the United States via diplomatic pouch from Lisbon and flew with his share of the seeds to Western Australia.

We made 194 seed collections in Spain and 48 in Portugal (table 1). Local boys did not assist in seed collection because they did not appear at collection sites as they had in Africa. We communicated with local people primarily in Spanish, although some understood French, and we used English in tourist accomodations.

Plant Introduction, Inspection, and Identification

Howard L. Hyland, Principal Plant Introduction Officer, Germplasm Resources Laboratory, Agricultural Research Service (ARS), U.S. Department of Agriculture (USDA), Beltsville, Md., handled our incoming seed collections when they arrived in the United States. He passed them through the USDA Plant Inspection Station in Washington, D.C.; obtained official taxonomic identifications from C. R. Gunn, Plant Taxonomy Laboratory, Plant Genetics and Germplasm Institute, ARS, USDA, Beltsville, Md.; assigned plant introduction numbers to seed collections and composed descriptions for each seed lot (based on our field notes and Gunn's identifications).

ACKNOWLEDGMENT

Howard Hyland acted as my adviser before and after the expedition and was my principal contact in the United States during the expedition. His experienced supervision of, and valued services to, the expedition contributed greatly to its success.

PROTEIN YIELD AND QUALITY OF FORAGE AS INFLUENCED BY LEGUMES

By R. E. Blaser [1/]

Much research has shown that legumes-grass mixtures stimulate live weight gains, animal growth, milk production, or reproduction efficiency above that for grasses fertilized with nitrogen. Early work in Florida showed that steer gains were around 70 percent higher with carpetgrass-clover mixtures than for grasses alone.[2/] Other work in later years in Washington, Mississippi, Virginia, Alabama, and Florida also shows that animal performance is augmented by the presence of legumes in the pasture mixture. This improved performance is not clearly understood but may be attributed to the protein content and higher digestibility of legumes, effects of hormones, and the fact that cattle eat more legumes. However, from the viewpoint of yield, higher pasture-carrying capacities and more animal products are usually obtainable from grasses fertilized with nitrogen than from grass-legumes mixtures without added nitrogen.

The yield and protein content of legumes or legume-grass mixtures are directly allied with the stage of plant growth at cutting and with management of the pasture. The protein content of stemmy legumes such as alfalfa and red clover declines sharply as plants grow from a leafy, vegetative stage to a stemmy morphology as in the full-bloom stage (table 1). For example, protein in the dry matter for these two legumes declines from around 30 percent for leafy growth to 15 percent or even less in a full-bloom, stemmy stage.

TABLE 1.--Protein as percentage of dry matter in alfalfa and red clover at various stages of growth

Legume	Stage of Growth: Leafy	Bud	One-tenth bloom	full bloom	Mature
Alfalfa	33.5	22.0	20.2	17.3	14.0
Red clover	29.3	20.5	19.5	14.0	11.0

Yields of alfalfa or alfalfa-grass mixtures are generally maximum when cut three times at full bloom or four times per year in an early-bloom stage (table 2). More frequent cutting (five to six harvests per year) at leafy young stages improves protein content and digestibility, but reduces yields and causes stands to be lost. White clovers are tolerant of close grazing but yields of such clover kept short are also lower than for taller growth.

1/ University professor Virginia Polytechnic Institute and State University, Blacksbury 24061

2/ Blaser, R. E., Glasscock, R. S., Killinger, G. B., and Stokes, W. E. 1948. Carpet grass and legume pastures in Florida. Univ. Fla. Agric. Exp. Stn. Bull. No. 453, 36pp.

A maximum yield of total protein from the pasture and high percentages in every harvest cannot be obtained simultaneously. The total yield of protein and the amount of protein in dry matter must be compromised. Cutting or grazing at early leafy growths causes high protein content in individual cuttings, around 30 percent of the dry matter; however, the low yield and stand losses depress protein yield per acre (tables 1 and 2). On the other hand, cutting at a full-bloom or mature stage gives forage with a low 10- to 14-percent protein level, resulting in low protein yields per acre even though forage yields are high. Thus, the protein content in alfalfa or red clover should be compromised to values of 16- to 20-percent protein in forage with high yields, resulting in a higher protein content per acre. Crude protein yield of 1,600 pounds per acre or 250 pounds of nitrogen per acre are obtainable from alfalfa with four one-tenth-bloom cuttings per year.

TABLE 2.--Dry-matter, protein, and nitrogen yields and persistence of alfalfa under various numbers of cuttings per year

Cuttings/year	Yields (lb/acre) Dry matter	Protein	Nitrogen	Persistence
3 full-bloom cuts---	8,000	1,150	180	Excellent
4 one-tenth-bloom cuts	8,000	1,600	250	Excellent
5 bud cuts----------	6,000	1,300	200	3 years
6 prebud cuts-------	5,000	1,250	200	1 year

It is well known that leguminous plants stimulate the yield of grasses. For example, according to data from Kentucky in table 3, the yields of a fescue-'Ladino' clover mixture without added nitrogen were somewhat higher than when nitrogen was added at the rate of 120 pounds per acre. It is estimated that the nitrogen in the harvested vegetation approximated 150 pounds of nitrogen per acre when fertilized with 120:87:125 mixture compared to 192 pounds of nitrogen per acre for a 0:87:125 mixture.

TABLE 3.--Yields from a 'Kentucky 31' fescue-'Ladino' clover mixture with and without added nitrogen in a fertilizer[1/]

Treatment	Protein (lb/acre)	Clover (pct of yield)
0:0:0----------------------------------	3,029	23
0:87:125-------------------------------	5,527	39
120:87:125-----------------------------	5,293	17

1/ Templeton, W. C., and Taylor, Timothy. 1958. Some effects of N, T, and K fertilizer on the botanical composition of a tall fescue-white clover sward. Agron. J. 58: 569-572.

Orchardgrass or tall fescue were grown in Maryland either alone under various rates of nitrogen application or with 'Ladino' clover. The yields of grasses grown without clover were 2,670 and 7,070 pounds with no nitrogen and with 160 pounds of nitrogen per acre respectively (table 4). When 'Ladino'

clover was grown without grass, the yields were depressed by fertilizing with nitrogen. The weed-free herbage yield from grass-ladino clover mixtures grown without nitrogen fertilizer was 7,700 pounds (dry weight) per acre. The grass fraction of this mixture amounted to 5,730 and the ladino clover 1,970 pounds per acre. Hence, grass was stimulated in yield and undoubtedly in nitrogen content by clover growing in association with it. According to these experiments, around 2,700 pounds of dry matter per acre was produced by the grasses without nitrogen as compared to an average of 7,700 pounds produced by the grass-'Ladino' mixture without nitrogen. It is estimated that the 5,000 extra pounds of canopy growth stimulated by clover added about 150 pounds of nitrogen to the top growth above the amount of nitrogen in grass without added nitrogen. The nitrogen content of the soil was not measured, but the improvement undoubtedly was appreciable.

TABLE 4.--Dry-matter yields over a 2-year period for various forages grown alone and in association with each other and with and without added nitrogen[1]

Forage and nitrogen combination	Weed-free forage yields (lb/acre)
'Ladino' clover, no N	3,850
'Ladino' clover, 160 lb N/acre	2,911
Grass,[2] no N	2,670
Grass,[2] 160 lb N/acre	7,070
Grass-'Ladino' clover,[2] no N:	
Mixed herbage	7,700
Clover fraction	1,970
Grass fraction	5,730

1/ Wagner, R. E. 1954. Legume nitrogen versus fertilizer nitrogen in protein production of forage. Agron. J. 46(5): 233-237.

2/ Grass data are averages for tall fescue and orchardgrass.

MAINTENANCE AND MANAGEMENT OF LEGUMES IN PASTURES

By Joe D. Burns [1/]

The careful maintenance of legumes in legume-grass pastures is very important today due to the high cost of nitrogen fertilizer, the generally poorer quality of perennial grass pastures, and the relatively high-quality forage possible from legumes.

Let's look at some of the factors which influence the longevity of mainly 'Ladino' white clovers in clover-fescue and clover-orchardgrass pastures.

Moisture supply through rainfall and irrigation is one of these factors, as is the height of the forage (as hay or pasture) when cut or grazed. The species of the associated grass, whether fescue or orchardgrass, and the variety of clover are also important. The planting arrangement as rows or as broadcast seedings also affects longevity. Rate and time of application of nitrogen and lime, phosphorus, and potassium levels are additional factors.

Research in Tennessee showed that in 3 dry years, irrigation maintained an estimated 40 to 50 percent clover content in orchardgrass with a yield of 3.66 tons of dry matter per acre. Without irrigation, the clover content decreased to 5 to 10 percent with a total dry matter yield of 1.75 tons.

Data from Alabama[2/] show that after 2 years of growth in northern Alabama a clover-fescue mixture contained 34 percent clover when clipped or grazed to simulate pasture management and only 18 percent clover when the mixture was managed for hay.

A grazing experiment in Tennessee[3/] included work with four mixtures, orchardgrass and 'Ladino' clover; orchardgrass, fescue, and 'Ladino' clover; fescue and 'Ladino' clover; and fescue and 'Ladino' clover treated with 80 pounds of nitrogen. At the end of 4 years, the orchardgrass and clover mixture contained 89 percent clover. 'Ladino' clover made up 39 percent of the clover, orchardgrass, and fescue combination and 35 percent of the untreated fescue and 'Ladino' mixture. The fescue and 'Ladino' which received the 80 pounds of nitrogen had only a 2-percent clover content. It was more difficult to maintain clover in fescue than in orchardgrass. The clover content was significantly lower when 80 pounds of nitrogen was added to the fescue and clover pasture.

'Ladino', 'Regal', and 'Tillman' varieties of white clover have lived longer and have produced more forage than 'Louisiana White Dutch'. 'Kenstar' red clover has produced higher yields than 'Kenland' and has lived for 3 production years. 'Kenland' red clover, besides producing lower yields each year,

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2/ Hoveland, C. S., and Evans, E. M. 1970. Cool season perennial grass and grass-clover management. Ala. Agric. Exp. Stn. Circ. 175, 21pp.

3/ High, Joe W., Jr., Safley, L. M., Long, O. H., Duncan, H. R., High, T. W., Jr. 1965. Combinations of orchardgrass, fescue, and Ladino clover pastures for producing yearling steers. Tenn. Agric. Exp. Stn. Bull. 388, 26pp.

lasted only 2 years.

In South Carolina and Alabama tests, the clover content of fescue and clover mixture was higher and the clover stand lasted longer when the fescue was planted in 18- to 20-inch rows than when planted as broadcast fescue. The competition for light, water, and nutrients by the fescue can be decreased by limiting the area seeded in this grass.

Along with the physical space available for growth, rate and time of application of nitrogen to a clover-grass mixture influence the clover content. Table 1 shows the results of a test in Virginia with nitrogen on a fescue-clover mixture.4/

TABLE 1.--The effect of time and rate of nitrogen applications on dry matter yield and clover percentage of a fescue clover mixture1/

Nitrogen (lb/acre)	Time of application	Dry matter (lb/acre)	Clover (percentage)
0	--	4,400	24
50	June	4,600	21
50	August	5,200	21
100	February	4,850	13
100	June	4,860	19

1/ From the Virginia Polytechnic Institute and State University, Blacksburg 24061.

Data on work with a fescue and clover mixture in North Carolina showed similar results (table 2).5/

TABLE 2.--The effect of time and rate of nitrogen application on 3-year average yield and clover percentage at end of 3rd year of a fescue-clover mixture1/

Lb/acre of N applied2/	Dry matter (lb/acre)	Clover (pct)
0	3,400	52
25	3,900	29
50	4,500	22
100	5,200	5

1/ From North Carolina State University, Raleigh 27607.

2/ These amounts were applied in February and again in September of each test year.

4/ Blaser, R. E., and Ward, C. W. 1952. Mimeographed information distributed at the Southeastern Pasture and Forage Crop Improvement Conference, Virginia Polytechnical Institute, Blacksburg 24061.

5/ Chamblee, D. S., Lovvorn, R. L., and Woodhouse, W. W., Jr. 1953. The influence of nitrogen fertilization and management on the yield, botanical composition and nitrogen content of a permanent pasture. Agron. J. 45: 158-164.

These data suggest that small amounts of nitrogen (less than 50 pounds per acre) will lower the percentage of clover in a clover and grass mixture slightly and that the heavier rates (100 to 200 pounds per acre) will severely lower the clover content in fescue and clover mixtures. Also, late winter and early spring applications may lower the clover more than early summer or fall applications. Work with fescue-clover pastures in Tennessee which were nitrated and grazed to a short 1-inch to 2-inch stubble indicates that a higher clover content can be maintained with grazing than when the fescue is allowed to accumulate.

The affects of lime, phosphate, and potash applications on clover growth have been well-documented in the literature. Lime applications have increased the yield of clover under acidic soil conditions. Adequate phosphorus levels have been especially beneficial in producing high yields of clover during the seedling year. Potash applications on grass and legume mixtures have maintained higher clover percentages when lime rates were high and when soil potash levels were low.

Soil moisture level affects the maintenance of clover in pasture mixtures. Where moisture is limited in soils subjected to very frequent droughts, there seems to be a need for reseeding with annual clovers or lespediza or a perennial legume such as sericea. For soils in areas of infrequent droughts, renovation (the reseeding of clovers) might be the best alternative.

With soils which maintain enough moisture for clover growth throughout the year, every effort should be made to supply the fertilizer, lime and management necessary to insure an adequate clover content for high forage production and a high-quality animal product. The need to maintain clover in pastures does not eliminate the opportunity for wise nitrogen use on clover-grass or grass pastures, but it does leave a challenge to find the best forage management systems for economical animal production.

CONTRIBUTION OF LEGUMES TO NITROGEN, PROTEIN AND FORAGE PRODUCTION IN THE SOUTHEAST

By W. Keith Wesley 1/

Cattlemen's interest in forage legumes is growing rapidly, not only because legumes are relatively cheap sources of N and protein, but because cattlemen are gradually becoming more aware of the value of forage quality and a balanced forage program.

Most forage grasses, such as 'Coastal' bermudagrass, are bred to respond to high rates of N fertilizer and produce high yields. Since the price of N fertilizers has doubled in the last year, many cattlemen are asking whether they can cut down or eliminate the use of commercial fertilizers on their pastures. The answer to this question is rather simple: they cannot afford not to fertilize their pastures. Without N, 'Coastal' bermudagrass yields drastically decrease, and more importantly, the protein content or quality drastically also decreases. This results in an increased cost for each pound of protein produced.

An abundance of high-quality forage with good seasonal distribution is the basis for beef production and profits. Economical production of this high-quality forage is the key to a successful livestock operation.

In the presence of the proper strains of Rhizobium bacteria, fertile legumes can fix rather large quantities of N. Table 1 gives N fixation values commonly reported for various legume crops. Overseeding of adapted legumes in warm- and cool-season grasses will allow the grass to utilize part of this fixed N and thus reduce N fertilization costs.

TABLE 1.--Average amounts of nitrogen fixed per acre by various legumes

Legume	N (lb/acre)
Alfalfa	194
'Ladino' clover	179
Red clover	114
Crimson clover	94
Arrowleaf clover	100
Lespedeza	85
Vetch	80
Lupine	125

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Knight and Watson[2] have reported that legumes overseeded in 'Coastal' bermudagrass increased total dry-matter production. Crimson and arrowleaf clovers were found to produce approximately one ton of dry matter per acre more than produced by 'Coastal' grown alone and fertilized with 200 pounds of N per acre (table 2).

TABLE 2.--Dry forage yields from clovers overseeded in 'Coastal' bermudagrass sod, averaged over 1968 and 1969

(Pounds dry matter per acre)

Forage	Clover	Grass	Total
Crimson	2,660	9,770	12,430
Arrowleaf	2,170	9,170	11,340
Red	5,600	4,440	10,040
White	6,520	3,680	10,200
Check:			
Bermudagrass with volunteer annual clover, no N		2,340	2,340
Bermudagrass with volunteer annual clover, 200 lb N/acre/yr		7,740	7,740

Knight and Watson also reported that winter dry-matter production from grass-legume mixtures was superior to both ryegrass (table 3) and tall fescue grown alone and fertilized with N (table 4).

TABLE 3.--Dry forage yields from ryegrass-clover mixtures and ryegrass supplemented with N

(Pounds dry matter per acre)

Components	Fall	Winter	Spring	Total
Ryegrass and subclover:1/				
Clover	648	834	1,959	3,442
Grass	1,092	863	2,287	4,243
Total				7,683
Ryegrass and crimson clover:				
Clover	527	1,055	2,973	4,555
Grass	1,142	979	2,081	4,202
Total				8,757
Ryegrass check2/	2,262	1,066	4,803	8,132

1/ Received 500 lb 0:20:20/acre at planting.
2/ Received 120 lb N/acre in 2 applications.

2/ Knight, W. E., and Watson, V. H. 1973. Legumes pay big dividends in pasture programs. Miss. Agric. For. Exp. Stn. Tech. Release C-15, 7pp.

TABLE 4.--Dry forage yields from tall fescue-clover mixtures and tall fescue supplemented with nitrogen

(Pounds dry matter per acre)

Components	Fall	Winter	Spring	Total
Tall fescue and subclover:1/				
Grass	1,230	1,182	1,966	4,378
Clover	346	489	1,748	2,585
Total				6,963
Tall fescue and crimson clover:1/				
Clover	1,063	1,898	2,201	5,162
Grass	291	539	1,402	2,232
Total				7,394
Tall fescue check2/	1,010	1,218	4,303	6,531

1/ Received 500 lb of 0:20:20/acre at planting.
2/ Received 120 lb of N/acre in 2 applications.

Legumes are generally high in digestibility. Their dry-matter digestibility usually ranges from 60 to 80 percent. Legumes grown in association with annual and perennial grasses generally provide a greater total production of forage, an extended grazing season, most of the N for the grass, and, last but not least, increased forage quality. These factors result in more milk and beef production and thus profit.

Cattlemen in the Southeast are fortunate in that they have a rather large number of forage legumes that are adaptable to their individual forage programs. The adaptation of a particular legume species will of course depend on the soil and climatic conditions of the area and the time in which the high-quality forage is needed most by the particular herd of cattle.

LEGUMES IN ANIMAL PRODUCTION SYSTEMS FOR THE UPPER SOUTH

By J. C. Burns [1]

INTRODUCTION

Beef producers have long recognized that legume or legume-grass forages usually stimulate higher production per animal than do non-legume forages. This higher production can occur even when the legume's digestibility is no greater than a corresponding non-legume. This inherent advantage of legumes, along with several other factors, forms the basis for determining the role of legumes in animal production systems.

The purpose of this paper is to evaluate the major factors determining whether or not legumes should be used in a producer's feeding system especially concerning their use through grazing in cattle production in the Upper South.

Desirable Forage Characteristics

High Dry-Matter Yields

The total dry matter that can be produced per unit of land area is of considerable importance to livestock producers who plan to use forage as a substantial part of the animals' feed. The amount of forage production can thus limit the size of the enterprise.

The yields of legume-grass mixtures are generally similar to those of well-fertilized pure grass stands during the first 3 to 4 years after establishment (table 1). Thereafter, the legume-grass mixture is generally inferior in production because the legume does not persist well. By the end of the fourth year, tall fescue continued to yield similarly to the second and third year, while the productivity of the 'Ladino' clover-tall fescue mixture decreased by 254 percent. Legume content also dropped 231 percent. This means that to maintain productive legume-grass stands, a rotation or reestablishment feature within the feed system will probably be necessary.

High Nitrogen Fixation

The legume's ability to fix elemental nitrogen is one of its major attributes. Much of this nitrogen, in time, becomes available to the companion grass crop or row crops that follow in rotation. Table 2 shows the nitrogen yield compared to the total dry matter produced in several grass crops.

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TABLE 1.--Successive yields of 'Ladino' clover-tall fescue compared to tall fescue[1]

Pasture	Harvest number	Yield (kg/ha)	Clover (percent) in			
			Spring	Summer	Fall	Mean
Second year:						
'Ladino'-tall fescue	5	6,551	52	55	36	48
Tall fescue[2]	5	4,643	--	--	--	--
Third year:						
'Ladino'-tall fescue	8	6,577	44	60	56	53
Tall fescue	8	6,440	--	--	--	--
Fourth year:						
'Ladino'-tall fescue	5	2,577	16	20	30	22
Tall fescue	5	5,466	--	--	--	--

1/ Chamblee, D. S. (1961, 1962, 1963). Forage Management Research. Dept. of Crop Sci., N. C. State Univ. Forage Annu. Rep. 1961, 1962, 1963. (Unpublished data).

2/ Tall fescue received 140 kg/ha of N in March and 84 kg/ha in September.

TABLE 2.--Added elemental nitrogen to several grasses necessary to equal the dry matter and nitrogen yields when these grasses are grown in a legume-grass mixture[1] (Kilograms per hectare)

Forage, length of study	Dry matter yield	Nitrogen yield
12 grasses, 5 years	136	238
Orchardgrass, 2 years	179	224

1/ Results from different studies, as discussed in Cowling, D. W. 1961. The effect of white clover and nitrogenous fertilizers on the production of a sward. J. Br. Grassl. Soc. 16: 281-290.

In the work reported by Holmes and Maclusky (table 2), cool-season grasses required an average of 136 kilograms per hectare of elemental nitrogen to compare with dry-matter of each grass when grown with a legume. The same grasses required an average of 238 kilograms per hectare of elemental nitrogen to compare with kilograms of nitrogen per hectare produced from each grass when grown with a legume. Wagner found similar relationship but a smaller difference for orchardgrass also shown in table 2.

These data show that a large quantity of nitrogen is fixed by legumes. Producers must consider the cost of buying commercial nitrogen for their pastures as compared to the cost of obtaining nitrogen through maintaining a suitable legume-grass mixture. Additional factors influencing their choice of nitrogen source are the availability of nitrogen, ease of purchasing, and the ecological impact of nitrogen losses into the ground water, although this loss has generally been small for pasture environments.

Desirable Animal Responses
High Daily Production

Sheep grazing short rotational ryegrass gained similarly to sheep grazing a perennial ryegrass-white clover pasture and better than sheep grazing perennial ryegrass alone (table 3). However, even these good gains from short rotational ryegrass increased when white clover was added to the pasture, showing the influence of the legume.

TABLE 3.--Live weight gains of sheep grazing pure stands of ryegrass compared to gains on ryegrass-white clover mixtures[1/]

Forage	Live weight at end of trial (kg)
Perennial ryegrass	47
Perennial ryegrass and white clover	56
Short rotational ryegrass	57
Short rotational ryegrass and white clover	63

1/ Rae, A. L., Brougham, R. W., Glenday, A. C., and Butler, G. W. 1963. Pasture type in relation to live weight gain, carcass consumption, iodine nutrition, and some rumen characteristics of sheep. J. Agric. Sci. 61: 187-190.

Similarly, daily steer gains (table 4) from tall fescue or orchardgrass grown in combination with 'Ladino' clover were consistently higher than gains from grass grazed alone and fertilized with 224 kilograms of nitrogen per hectare. Yearling steers and heifers gained similarly (table 5).

TABLE 4.--Daily gains per steer and steer days and gains per hectare, averaged over 10 years[1/]

Forage	Daily gain/steer (kg)	Steer (days/ha)	Gains (kg/ha)
Tall fescue and 'Ladino' clover	0.46	749	346
Tall fescue and nitrogen[2/]	0.41	974	413
Orchardgrass and 'Ladino' clover	0.58	621	369
Orchardgrass and nitrogen[2/]	0.49	752	373

1/ Blaser, R. E., Bryant, H. T., Hammes, R. C., Jr., Boman, R. L., Fontenot, J. P., and Polon, C. E. 1969. Managing forages for animal production. Va. Polytech. Inst. Res. Div. Bull. 45, pp. 29-86. Steer days based on 318-kg yearlings.

2/ Fertilized each year with 224 kg of N/ha from ammonium nitrate.

TABLE 5.--Yearling gains and animal days per hectare from legume-grass and pure grass pastures, averaged over 4 years 1/

Forage	Daily gain/yearling (kg)	Animal days/ ha
'Ladino' clover-tall fescue	0.92	430
'Ladino' clover-orchardgrass	0.83	464
Tall fescue + 'Coastal' bermudagrass	0.50	940

1/ Gross, H. D., Goode, L., Gilbert, W. B., and Ellis, G. L. 1966. Beef grazing systems in Piedmont, North Carolina. Agron. J. 58: 207-110.

Milk production from lactating dairy cows was sustained at higher levels and for a longer time on an orchardgrass-'Ladino' and tall fescue-'Ladino' mixture (table 6), than on tall fescue topdressed with 224 kilograms of nitrogen per hectare each year. This factor can be of considerable importance in cow-calf enterprises where calf performance is greatly altered by the lactating ability of the cow.

TABLE 6.--Effect of several forages on persistency of milk production of lactating cows, from a 3-year study 1/

Forage	Percentage of control week's production 2/	Total digestible nutrients (kg/ha)
Orchardgrass-'Ladino' clover 3/	98	1,934
Tall fescue-'Ladino clover 4/	89	2,005
Tall fescue 5/	81	2,608

1/ Seath, D. M., Lassiter, C., Bastin, G. M., and Elliot, R. 1954. Effect of kind of pasture on the yield and TDN and on persistency of milk production of milk cows. Ky. Agric. Exp. Stn. Bull. 609, pp. 1-11.

2/ Production in the last week of the 4-week test period as a percentage of the production in the week just prior to the start of the test period.

3/ 'Ladino' of excellent quality.

4/ 'Ladino' stand greatly reduced by 3rd year.

5/ Topdressed with 244 kg of N/ha each year.

Evaluation of calf gains (table 7) on a 'Ladino' clover-tall fescue mixture and tall fescue pastures compared to gains when these are grazed as a system with 'Coastal' bermudagrass clearly shows the value of the legume-grass mixture. 'Coastal' bermudagrass and tall fescue formed a system which significantly increased calf gains compared to tall fescue alone. Cow gains (table 8) were not found to be significantly different between the mixture, the mixture grazed insequence with 'Coastal' bermudagrass, and tall fescue grazed in sequence with 'Coastal' bermudagrass.

TABLE 7.--Combined means (between-animal analysis) for adjusted gains of test calves grazing legume-grass and pure grass pastures over a 2-year study (Kilograms per head)

Forages	Early April to late May	Late May to Mid-September	Season
'Ladino' clover-tall fescue	43.3	79.9	122.1
'Ladino' clover-tall fescue + 'Coastal' bermudagrass[2/]	----	73.1	118.1
Tall fescue + 'Coastal' bermudagrass	----	68.3	105.0
Tall fescue[2/]	37.3	56.1	93.6

1/ Burns, J. C., Goode, L., Gross, H. D., and Linnerud, A. C. 1973. Cow and calf gains on Ladino clover-tall fescue and tall fescue, grazed alone and with Coastal bermudagrass. Agron. J. 65: 877-880.

2/ 'Coastal' bermudagrass and tall fescue were topdressed with 185 kg of N/ha.

TABLE 8.--Combined (between-animal analysis) for adjusted gains of tester cows grazing legume-grass and pure grass pastures over a 2-year study[1/] (Kilograms per head)

Forages	Early April to late May	Late May to Mid-September	Season
'Ladino' clover-tall fescue	22.9	27.4	50.5
'Ladino' clover-tall fescue + 'Coastal' bermudagrass[2/]	----	31.1	53.8
Tall fescue + 'Coastal' bermudagrass[2/]	----	37.0	49.0
Tall fescue	11.5	12.8	23.9

1/ Burns, J. C., Goode, L. Gross, H. D., and Linnerud, A. C. 1973. Cows and calf gains on Ladino clover-tall fescue and tall fescue, grazed alone and with 'Coastal' bermudagrass. Agron. J. 65: 877-880.

2/ 'Coastal' bermudagrass and tall fescue topdressed with 185 kg of N/ha.

All animals used in evaluation (sheep, yearling, calves, and milk cows) consistently performed better on a legume-grass mixture than on pure grass pastures.

High Production Per Hectare

Animal days per hectare and animal product per hectare are two criteria used to quantitatively measure pasture productivity. Animal days per hectare expresses the yield of a pasture in terms of the number of standard or test animal days that can be supported during the grazing season. However, animal product per hectare is generally the unit of most interest in grazing trials since it expresses the combination of the quality and quantity of the pasture

consumed (animal days X product per animal).

Generally, legume-grass pastures do not provide as many animal days per hectare as do well-fertilized pure grass pastures (table 4). On the other hand, the higher product per animal obtained from legume-grass pastures, when multiplied by the animal days per hectare (fewer than with pure grass), will partly offset this difference.

A warm-season grass grazed in sequence with a cool-season grass greatly increased animal days per hectare (table 5). This same effect of increased animal days per hectare would be expected when grazing either mixture in combination with 'Coastal' bermudagrass. However, this comparison was not made in the study. Furthermore, tall fescue pasture yielded appreciably more kilograms of total digestible nutrients per hectare as calculated from milk production (compared to a 'ladino' clover-grass mixture) even though milk produced per day declined more quickly (table 6).

Thus, a legume-grass mixture has a lower carrying capacity and consequently lower animal production per unit area as compared to a well-fertilized pure grass pasture.

Forage Choices

The factors which I believe to be of major importance in decisions concerning the use of legume-grass and pure grass pastures for livestock enterprises are summarized in table 9. Factors 1 through 6 have been previously discussed. Factor 7 is easily considered since we do not have reliable, productive, midsummer legumes.

TABLE 9.--Comparative factors to consider in choosing grass-legume or grass pasture

Factors	Grass-legume mixture	Pure grass stands
1. Dry matter production after 3 to 4 years	Less	More
2. Perenniality	Less	More
3. Nitrogen application	Less	More
4. Animal performance	More	Less
5. Animal days/unit area	Less	More
6. Animal product/unit area	Less	More
7. Midsummer production	Less	More
8. Intensity of pasture management:		
Animal standpoint	Less	More
Pasture standpoint	More	Less

Management Differences

Managing a legume-grass mixture is quite different from managing a pure-grass pasture (factor 8). The legume-grass mixture requires less intensive grazing management to maintain good animal performance than does pure grass. Generally, quality drops in grasses in the Eastern United States when they grow much above 10 centimeters. Above this grass height, animals begin to

spot-graze pastures severely, causing a poor feed situation to develop. This problem does not usually develop with legume or legume-grass mixtures.

Management of a legume-grass mixture is more difficult than managing pure grass pasture because of difficulties in maintaining good balance between the legume and grass components. Frequently, the legume decreases due to disease, insect damage, and frequent defoliation.

Total Production

Each farmer must consider his own enterprise before deciding which forage crop to grow. He should especially remember that production per animal is a function of total daily nutrient intake.

$$\underset{\text{(meat, milk, etc.)}}{\text{Production/animal}} = f\left(\begin{array}{c}\text{Dry matter}\\ \text{intake}\end{array} \times \begin{array}{c}\text{Digestibility of}\\ \text{dry matter}\end{array}\right) \quad (1)$$

Furthermore, production per hectare depends on gain per animal and animal days per hectare.

$$\underset{\text{(meat, milk, etc.)}}{\text{Production/ha}} = \begin{array}{c}\text{Production}\\ \text{per animal}\end{array} \times \text{Animal days/ha} \quad (2)$$

These relationships are important as we consider the five major forage options available to most producers. A farmer can grow a legume-grass mixture, a cool-season grass, a warm-season grass, a legume-grass mixture and a warm-season grass, or both a warm- and cool-season grass. The best choice of forage for a particular livestock enterprise depends on the adaptability of the species being considered and the cost of establishment, maintenance, and harvesting of the required forage relative to expected returns. Each animal must gain or produce sufficiently (equation 1) on the chosen forage to give good economic returns. This point should be considered separately from animal product per hectare. However, depending on the enterprise and the price structure, some reduction in production per animal in favor of more animals may return more profit to the enterprise (equation 2).

A Potentially Ideal Forage System

If the major farm enterprise is based on a short-term rotation of three to four years, the farmer should consider a legume-grass mixture in combination with a summer annual grass. If a portion of the land area can be left in pasture, a perennial warm-season grass would be the choice. When the farm enterprise requires a long term pastures, pure grass stands with periodic introduction of legume may be a good choice.

Ideally, a producer would plant forage species that provide both maximum production per animal and permit maximum production per hectare. This is partially possible with a legume-grass mixture grazed in sequence with a warm-season grass if the legume-grass component of the system can be reestablished every 3 years. Assuming that the legume and grass can be reestablished, this combination permits the producer to take advantage of the higher animal performance from the legume-grass mixture during the spring and fall, without much sacrifice in animal days per hectare, making it superior to a single cool-season species. Furthermore, he can rely on the warm-season component for its

high carrying capacity in animal days per hectare during the summer.

Balancing the advantages and disadvantages of a legume-grass mixture with a pure grass as in this system should result in very adequate production per animal and more product per hectare compared with the other available options.

PROBLEMS ASSOCIATED WITH LEGUMES

By W. E. Monroe [1]

Legumes have long been recognized as crops that improve the quality of forage and are valuable for the nitrogen they add to the soil. However, there are certain problems associated with legumes as forage crops.

Maintaining a proper balance between grasses and legumes has always been a struggle. This problem has become even more serious during the years when nitrogen fertilizers have been plentiful at depressed prices. The grazing management used is the key to maintaining a proper balance. Research and experience have shown that the best way to maintain a proper balance is to graze both grasses and legumes close during their flush season of growth to prevent them from crowding each other out.

Soil fertility is also a limiting factor in maintaining clover in a grass sod. Under Louisiana conditions, and soil deficient in phosphate and potash must receive an application of these each fall to obtain the best results possible.

Bloat in cattle grazing clover in the spring has caused severe damage in the past and had actually caused many Louisiana producers to destroy their stands. Many control measures have failed, but at last there is a dependable preventive. Research conducted at the Louisiana Agricultural Experiment Station, Baton Rouge,[2] and confirmed by other stations has proven the Poloxalene will control bloat when used properly. Poloxalene-treated blocks must be placed in the pasture where the animals will have easy access to them, such as near the water source or in areas where cattle usually rest, because daily intake of Poloxalene is essential to control.

Weed control is a problem in clover production. The older strains of clover that were slow growing, such as native 'Louisiana White', could tolerate relatively high rates of 2,4-D, allowing good weed control. The improved strains, such as Nolin's 'Improved Louisana White' of 'Louisiana S-1', are fast-growing varieties and are susceptible to 2,4-D injury when it is applied at rates in excess of 0.75 pound per acre. This makes weed control a real problem, especially with the hard-to-kill weeds.

A source of seed of known genetic purity is more of a problem than most realize. Very little seed of 'Louisiana S-1' is produced by growers in Louisiana. Western-grown seed are being planted. There is nothing wrong with using western seed if the genetic purity is assured. However, a great deal of uncertified seed of 'Louisiana S-1' is now coming into the State, and this seed may or may not be true to variety. Unless a grower can purchase certified seed from the Western States, he would be much better off using Southern-grown

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seed. At least he will know that these seed are adapted to the area.

Effective inoculation must not be overlooked. It is estimated that only a small percentage of the clover grown in the state is effectively inoculated; thus, the amount of nitrogen fixed in the soil is cut to a minimum. Inoculation would greatly increase nitrogen fixation.

When all the problems associated with legumes are considered, control of them all seems to depend on good management.

AGRICULTURAL RESEARCH IN ARKANSAS

By L. O. Warren [1]

In this paper, I wish to describe the organizational structure of the Arkansas Agricultural Experimental Station, to identify some of the challenges to agricultural research scientists, and to provide a few examples to show how we are approaching some of these problems in Arkansas.

The Arkansas Agricultural Experiment Station includes a section called Agricultural Publications and nine divisions, the Departments of Agricultural Economics and Rural Sociology, Agricultural Engineering, Agronomy, Animal Sciences, Entomology, Home Economics, Horticulture and Forestry, Horticultural Food Science, and Plant Pathology. Besides the main station at Fayetteville, there are seven branch stations and five substations in various areas of the state.

All research work is carried out under the direction of project leaders who may supervise more than one project at more than one station. Project leaders also frequently establish research studies of agricultural interest on land belonging to farmers or industrial cooperators, in all sectors of the state.

We presently have approximately 245 research projects underway, many of them multidisciplinary in nature. These studies impinge on the lives of all citizens of the state in some way. Our support comes from federal, state, and industrial sources. State funds provide 42 percent of our resources; federal funds, 26 percent; grants, 7 percent; and cash sales, 25 percent. As in every state, additional support is desired to expand services to the people of the state.

The ultimate challenge to agricultural research is to provide food and fiber in a healthful environment at the least possible cost and in amounts to satisfy human needs. That agricultural research has been successful is evidenced by the fact that in the United States only 17 cents of every disposable dollar of income is spent for food as compared to higher ratios in other countries. This has been achieved even though operating expenses have steadily risen, the available acreage of crop land is decreasing by 2.2 million acres annually, farm labor is increasingly difficult to find, and many other factors affecting crop production have increased production costs.

It is estimated that 4 percent of the population feeds the remaining 96 percent. In addition, our population increases annually, and our life span has increased by 20 years, so more people are living longer and eating better, requiring ever-increasing production to satisfy basic human needs. Aside from domestic needs, developing nations of the world are becoming increasingly dependent on American agricultural commodities to satisfy food and energy requirements.

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Thus, all things considered, it is necessary for agricultural technology to develop production systems that provide a profit to the producer and satisfy the needs for food and fiber. This requires team effort in many disciplines, engineering, plant breeding, pest control, soil research, farm management, marketing, processing, utilization, and others. It also requires a delivery system for new knowledge and technology. Thus, the Cooperative Extension Service has a vital function in the development of our production programs.

As an example of problem solving, let us consider rice. In the poorer countries of the world, rice is harvested by hand and threshed by hand or with rudimentary equipment. Our research results in this country allow us to grow rice, harvested and move it to the elevator with few man-hours involved. In Arkansas, since 1952, as the result of research in pest control, soil fertility, farm management, water management, breeding new varieties, and farm machinery, our yields have increased from 2,500 pounds to 5,000 pounds per acre.

The mechanization of cotton production and the systems approach to production problems have brought increased yields. Pest management has resulted in one of the lowest rates of losses to boll weevil attack in the Cotton Belt. Conservation of moisture in double-cropping programs is a critical problem. Research is underway which has already shown that sorghum and soybean crops can be grown under no-till systems with satisfactory yields.

Fruit and vegetable crops are important to the economy of the state. While many of the conventional varieties are suitable to our conditions, there is plenty of room for breeding new varieties for Arkansas conditions and for mechanical harvesting. To this end, two new blackberry varieties suitable for mechanical harvesting have been released. A mechanical harvester was developed concurrently. New strawberry varieties, suitable for mechanical harvesting, are coming out of our breeding program, along with a mechanical harvester.

A team approach to forage and cattle production has been demonstrated vividly on a tour given to those who attended this conference. In terms of beef production, this has been one of the most effective programs in the South and one of which we feel we are justly proud. Arkansas ranks first in the nation in broiler production. We have a strong program underway in poultry research aiming toward more efficient production with less labor.

These are only a few examples of research thrusts at the Arkansas Agricultural Experiment Station. Our program is a productive one, providing benefits for the people of Arkansas. In addition, due to our interaction in regional research, we contribute as well as receive benefits derived from such programs.

DEVELOPING NEW VARIETIES OF VETCH AND LESPEDEZA SERICEA

By C. Cooper King, Jr. 1/

For several years, E. D. Donnelly has done research on improvement of vetch and lespedeza sericea. In recent years I have worked with him on forage management experiments using his material.

Donnelly (3)[2/] used interspecific hybridization to develop hard-seeded vetch. Early experiments by Donnelly, Hoveland, and Patterson (7) and Donnelly and Hoveland (6) showed that hard-seeded vetch reseeded well on summer grass sod. Donnelly, Watson, and McGuire (8) concluded that hard-seededness can be explained by two-gene inheritance.

The first attempt to obtain grazing data from one of the hard-seeded lines, 'Nova', was conducted at the Lower Coastal Plain Substation at Camden, Ala. The initial interseeded stands on both 'Coastal' bermudagrass and bahiagrass were good. The following fall volunteer stands were obtained on both grasses. However, Sclerotinia trifoliorum developed into damaging proportions and we were unable to obtain grazing data.

We were more successful in another experiment in which 'Nova' was used as a green manure crop in rotations with summer crops (9). It had already been established that late-planted crops such as soybeans and sorghums could be grown after the vetch had matured to seed. To plant cotton or corn on time, however, it was necessary to turn the vetch ahead of seed formation. Thus, for 'Nova' to volunteer in cotton or corn, seed must remain viable in the soil for 2 or more years.

In the fall, 10 pounds per acre of 'Nova' seed were interseeded in standing cotton stalks. Hand-harvested samples in the spring showed a seed yield of 1,440 pounds per acre, and hard-seed percentage was 83 percent. This yield of seed was incorporated 6 to 8 inches deep into the soil, and five treatments were studied (table 1). These results established that the reseeding characteristic of 'Nova' vetch could be used with summer crops using clean cultivation if the vetch was allowed to produce seed once every 2 or 3 years.

Since releasing two new cultivars of sericea, 'Serala' (1) and 'Interstate' (2), with the improvements of having more leafiness and being more fine stemmed, Donnelly has concentrated his sericea breeding efforts toward developing lines low in tannin (4, 5). We have established 20-acre pastures each of 'Serala', 'Interstate', and 'Line 106' (low in tannin) and are comparing the performance of cattle grazing them with that of cattle grazing a 20-acre summer grass pasture. Each test pasture was stocked with 12 cows and their calves in 1972 and with 15 cows and claves in 1973.

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2/ Underlined numbers in parentheses refer to items in "Literature Cited" at the end of this paper.

TABLE 1.--Four-year average yield for row crops grown in rotation with 'Nova' vetch, Tallassee, Ala.

Field Crops		Yield/acre
Grain sorghum		50 bu.
Soybeans		27 bu.
Soybeans)	two-year rotation	27 bu.
Cotton)		2,400 lb.
Soybeans)	two-year rotation	27 bu.
Corn)		58 bu.
Soybeans)	three-year rotation	28 bu.
Corn)		58 bu.
Cotton		2,400 lb.

During both years, the adjusted 270-day weights of calves from the 'Interstate' pastures were significantly lower than weights of those on the summer grass while weights of calves grazing 'Line 106', 'Serala' and summer grass did not differ significantly among themselves (table 2). Interestingly, the calves from the low-tannin pastures averaged slightly heavier than calves from the grass pastures; however, a weak stand of 'Line 106' caused an early reduction in stocking rate and makes a true evaluation of this new material difficult.

TABLE 2.--Calf performance on sericea and summer grass pastures, Tuskegee, Ala.

Pasture	Adjusted average 270-day weight 1/		
	1972	1973	Mean
Summer grass	492a	431a	462
'Interstate'	409b	390b	400
'Serala'	470a	409a	440
'Line 106' (low-tannin)	--	446a	--

1/ Weights having a letter in common are not significantly different at the 0.05 level of probability.

Donnelly's present emphasis on lespedeza sericea is the development of a higher level of resistance to *Sclerotium rolfsii* in his low-tannin material. He is also selecting for resistance to *Sclerotinia trifoliorum* from 'Nova' stands established from irradiated seed.

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COOPERATIVE EXTENSION SERVICE IN ARKANSAS

By C. A. Vines [1]

Arkansas has 33.2 million acres that can easily be divided in to four regions. The Ozark Highlands in the northwest portion of the state make up about 20 percent of the state. The principal grasses in this area are cool season. The west-central area includes the Arkansas Valley Uplands and Ouachita Mountains. This is a transition zone between warm and cool-season grasses, but it is essential that both warm and cool-season species be established in pasture programs here. The coastal plains in the southwest have predominately warm-season grasses which are stored for winter feed. The Delta includes the eastern one-third of the state. It is planted mainly with soybeans, cotton, and rice, with very little pastureland.

Here is a brief sketch of our changing view towards pastureland in Arkansas. We went from row crops to pasture about 25 years ago. The major grasses were native and common bermudagrass that came into old cotton fields. We knew very little about pasture management, and we fertilized pastures every 5 years with 150 pounds of 10:20:20, whether it was needed or not.

No improved varieties were introduced in the 1950's and a big push was made for soil testing and fertilizer use. Most everyone used their fertilized, improved varieties for hay, and grazed lower quality, unfertilized land. In the 1960's, we began to talk about running a cow to the acre and practicing grazing management. Now we are seeing these practices carried out on many farms.

We have over 9 million acres of grazing land; however, about 3 million of this is unimproved woodland pasture. About 2 million acres is considered improved pasture, and the remaining 4 million acres is unimproved grassland.

The prevalent beef enterprise in Arkansas is the cow-calf system, consisting of raising calves from brood cows and selling the calves at weaning. A few producers are keeping their own calves or buying weaning calves and carrying them through the winter on temporary pasture.

We now have more than 2 million beef cattle in Arkansas, almost double the number in 1959. Most of the beef cow herds in Arkansas are small, consisting of less than 100 mother cows. Many of the owners are not full-time farmers. We also have almost 100,000 dairy cattle in the state. Gross sales from beef and dairy products in the state totaled $252 million in 1972, which was second only to soybean sales. In 1973, income from these two sources was estimated to be $354 million.

The main source of energy for livestock in the state is forage with little grain being fed. This emphasized that forage production in an intergral part of the economy of Arkansas. And for the first time, we now have an extension

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1/ Director, Cooperative Extension Service, P. O. Box 391, Little Rock, Arkansas 72203. Mr. Vines resigned in October 1974 and became Interim Vice President, University of Arkansas. Mr. Kenneth S. Bates is now Director.

specialist who has responsibility solely in the field of pastures and forages. Approximately 10 to 15 other specialists devote a portion of their time to forage production and utilization. These specialists integrate their programs with each other and with those of their research counterparts at the university in an overall coordinated effort to improve forage production and utilization in the state.

Our extension efforts in pastures and forages extend into many areas, but major emphases are placed in the areas of soil testing, demonstrations, and 4-H projects, along with educational meetings and short courses.

Often our activities are carried on in cooperation with another organization such as the Agricultural Stabilization Conservation Service, the Arkansas Forage and Grassland Council, the Arkansas Plant Food Educational Society, the Farm Bureau, and the Cattlemen's Association. There are approximately 50,000 pastureland soil samples tested by the university each year, with recommendations written by the Extension Service. Many of these analyses used in securing funds from ASCS programs.

We at the Cooperative Extension Service cooperate with the Arkansas Plant Food Educational Society in conducting the year-round Bull Unit Demonstrations with 30 cows on 30 acres, year round. We offer the technical assistance and the APFES offers a portion of the financing. We work closely with the Arkansas Forage and Grasslans Council, Cattlemen's Association, and the Farm Bureau in conducting short courses and providing speakers for their groups.

One of our outstanding 4-H projects has been the backgrounding project, in which local group finances the buying of calves, fertilizer, and production needs and teaches the club member all facets of backgrounding.

We are establishing demonstrations on each of our recommended practices, and currently have a weed control demonstration in each county of the state.

Our program in the future will emphasize better utilization and management to help producers grow high-quality forage at a lower cost. Recent information points out that we are using 2 to 3 acres of improved pasture to run one cow. We have the potential to lower this to 1 to 1½ acres and add almost another million cattle without adding any additional improved pasture. Seven million acres of unimproved grassland is now supporting one cow per 6 acres. This carrying capacity can also be easily doubled with proper management. Arkansas is truly a "land of opportunity" for the cattle industry.

PASTURE PRODUCTION AND MANAGEMENT IN ARKANSAS
PAST, PRESENT, AND FUTURE

By A. E. Spooner and Maurice L. Ray 1/

The earliest grazing experiments in Arkansas on record were initiated in 1933 at Hope and Mariana and concluded in the 1937-38 season. Data from two of these experiments are in tables 1 and 2. The next set of experiments was conducted at Batesville beginning in 1953 and ending in 1961. These data are in table 3, 4 and 5.

TABLE 1.--Grazing trials on pastures at Hope, Ark. 1933-38

Species	Fertilizer/acre/yr	Steer gains (lb/acre)	Returns/acre above fertilizer costs 1/
Carpetgrass------	None-------------------------	297	$17.82
Carpetgrass------	200 lb 20% superphosphate-----	308	14.98
Bermudagrass-----	100 lb sodium nitrate---------	213	10.90
Bermudagrass-----	145 lb 20% superphosphate-----	379	26.62

1/ Beef gains valued at 6¢/lb; N at 11.8¢/lb; and P205 at 7.3¢/lb.

TABLE 2.--Grazing trials on common bermudagrass at Hope and Marianna, Ark. 1933-37

Location	Fertilizer/acre/yr	Steer gains (lb/acre)	Returns/acre above fertilizer costs 1/
Hope-----	140 lb 20% superphosphate + 1 ton lime-	379	$19.70
Marianna-	None-----------------------------------	314	18.84
Marianna-	100 lb sodium nitrate------------------	388	21.40
Marianna-	400 lb 4:10:4--------------------------	413	17.98
Marianna-	140 lb 20% superphosphate + 1 ton lime-	559	30.50

1/ Beef gains, valued at 6¢/lb; N at 11.8¢/lb; and P205 at 7.3¢/lb. Lime prorated at $1.00/acre/yr.

1/ Professors, Agronomy and Animal Science Departments, respectively, University of Arkansas, Fayetteville 72701.

TABLE 3.--Grazing trials on common bermudagrass at Batesville, Ark. 1947-52

Fertilizer/acre/yr	Steer gains (lb/acre) 1947-49	Steer gains (lb/acre) 1950-52
0:120:0	330	416
0:40:0	247	---
None	59	63
33:40:60	---	272

TABLE 4.--Grazing trials on common bermudagrass at Batesville, Ark. 1953-55

Fertilizer/acre/yr	Steer gains (lb/acre)
None	119
0:40:0	195
0:120:0	290
60:60:30	253
66:50:50	242
132:50:50	297

TABLE 5.--Effects of nitrogen fertilization on steer gains on common bermudagrass at Batesville, Ark. 1959-61

Fertilizer/acre/yr	Steer gains (lb/acre)
0:90:0	165
50:90:0	237
100:90:0	297
200:90:0	354

The University of Arkansas acquired 500 acres of land at Newport in 1959 from the Navy. This land was designated as the Beef Substation and was to be used for pasture and beef cattle research. Grazing experiments were initiated in 1960 and have run continuously to date. The data given in table 6 is from one of the early experiment conducted at this station.

TABLE 6.--Grazing trials on common bermudagrass at Newport, Ark., 1960-63

Fertilizer/ acre/yr	Acres/ steer	Steer gains (lb/acre)	Hay (tons/acre)	Average daily gain (lb)	Average crude protein (%)
None	2.0	76	0.00	1.06	8.03
50:25:25	1.5	99	.69	1.03	8.88
100:50:50	1.0	170	1.08	1.18	11.45
200:100:100	.5	268	1.00	.93	12.00

In 1962, the University leased 1,000 acres of land at Hope, of which approximately 450 acres were designated for grazing experiments. Steer and cow-calf experiments were initiated in 1963, and summaries of data from some of these are in tables 7 and 8.

TABLE 7.--Grazing trials on common and coastal bermudagrass at Hope, Ark., 1963-66

Fertilizer/ acre/yr	Acres/ steer	Steer gain (lb/acre)	Fertilizer costs/acre1/	Gross returns/ acre2/	Returns/acre above fertilizer costs
60:60:60---------	2.2	299	$13.80	$ 89.70	$ 75.90
4 tons chicken litter----------	2.7	397	20.00	119.10	99.10
Equivalent of 4 tons litter-----	3.3	442	35.90	132.60	96.70
600:300:300------	5.9	694	96.00	208.20	112.20

1/ Applied as commercial fertilizer, 216:132:96.
2/ N at 10¢/lb, P205 at 8.5¢/lb, and K20 at 6¢/lb.

TABLE 8.--Cow-calf data from grazing trials on common bermudagrass and tall fescue at Hope, Ark. 1963-66

Kind of grazing	Acres/ cow	Cow weight (lb)	Weaning weight of calf (lb)	Lb of calf weaned/acre
Light	3.00	919	408	114
Moderate	2.00	916	414	176
Heavy	1.25	834	342	213

The University of Arkansas purchased 11,850 acres of land in one tract in 1964 near Colt. Pasture and beef cattle will eventually occupy about 4,500 acres of this tract which has become known as our Pine Tree Station. We are using this station to check out some of our ideas on grazing systems, such as determining acres needed per cow-calf unit and deferred grazing practices, and to furnish calves and young cows of known breeding for experiments located at the other stations. We have been able to increase our weaning weights over the past 6 years by about 60 percent through good pasture and cow herd management. We have found that, using fertilized land, a cow-calf unit can be grazed year-round on 1 1/2 acres. We have made maximum use of tall fescue in our programs at this station and have decided that we should use about 2 acres of tall fescue to each 1 acre of bermudagrass or bahiagrass.

Backgrounding and feeding to slaughter weight and grade have been a part of our overall experimental program. This work has been done at the Beef Substation and on leased land near Marianna. We have used most of the Arkansas-grown grains and byproducts of the rice and soybean industries in drylot feeding for the past 15 years. We have data available on our covered, concrete-based drylot feeding facility which handles 240 head of cattle. We have fed

much grain to cattle on pasture at the Marianna station. The data in table 9 compares feeding on tall fescue-white clover to drylot feeding. We found that grazing on Arkansas pasture was an acceptable way to feed cattle.

TABLE 9.--Fescue-white clover versus drylot for finishing yearling beef steers at Marianna, Ark. 1966-70

Measurement	Drylot	Pasture
Days on feed	66.00	66.00
Initial weight----lb	770.00	772.00
Final weight----lb	970.00	980.00
Average daily gain----lb	3.03	3.15
Carcass grade[1]	11.40	11.70
Grain consumed per head per day---lb	21.40	20.80
Grain required per lb of gain-----lb	7.10	6.60

1/ Choice=13; good=10.

Our research work at present is designed to further evaluate systems of cow-calf unit grazing, considering such factors as pasture needs related to cow size pasture needed, the proper use of fertilizers, maintenance of legumes, harvested feeds, and stockpiling of tall fescue to eliminate hay feeding in the winter. Rainfall distribution is a real problem in producing high-quality forage year round. At the Beef Substation, we are using irrigation to supplement rainfall as necessary to produce high-quality forage for backgrounding and finishing steers on pasture. We have been able to maintain growth of tall fescue, bromegrass, and white clovers throughout the summer by supplying an effective 1 inch of irrigation during any week that we do not receive an inch or more of rainfall.

There are many problems whose answers are important if we researchers are to continue to help farmers who grow forages and pastures. We need a warm-season perennial legume that will compete with bermuda, bahia, and dallis and will produce a large amount of high-quality forage, as well as a cool-season perennial grass that will produce well and persist in the light-textured hill soils of southern Arkansas. We need to improve the quality of forage we produce and make more efficient use of our pasture lands by utilizing each acre to its fullest potential. More work must be done on harvest, storage, and the economics of harvested forages. We need to develop a checkoff on the cattle sold in Arkansas and to earmark this money for cattle and forage research and extension work.

We who are researchers need to get closer to the farmer so that we can anticipate his needs rather than work on pet projects which have little or no use to the farmer. We need complete cooperation among all researchers and extension people who work with forages and cattle so that a complete program can be offered to the farmer. I believe that the members of the Southern Pasture and Forage Crop Improvement Conference can work out such a successful, complete program.

DEVELOPING NEW VARIETIES
OF ANNUAL CLOVERS

By W. E. Knight [1]

INTRODUCTION

Perhaps at no other time in the history of the United States has competition for land resources been so keen among the commodity crops. In many cases, this means that pasture crops will be grown on thinner, marginal soils which are undesirable for production of cotton, soybeans, corn, and wheat. The greatest opportunity for success on these soils is to maximize forage production in the fall, winter, and spring when rainfall is usually adequate, drought is less likely to occur, and temperatures are generally more favorable for succulent growth. Anthony et al. (2)[2] discussed the results of a number of grazing trials in Alabama which show higher average daily gains, higher total gain per animal, and higher slaughter grade when cool-season forages are used compared to warm-season species.

For many years, crimson clover, *Trifolium incarnatum* L., has been used with cereal grains and ryegrass to provide high-quality cool-season pastures (8, 19). In recent years, arrowleaf clover, *Trifolium vesiculosum* Savi., has been used successfully and is preferred in some management systems because it matures 6 to 8 weeks later than crimson clover (2, 10, 20).

The annual clovers not only contribute quality to cool-season pastures but provide nitrogen for the associated grass or cereal and contribute to animal health as well (5, 7). Problems with fescue foot, grass tetany, and similar maladies are minimized when grass-legume mixtures are properly utilized. As the fertility of thin, marginal pasture land is improved with annual clovers, white or red clover and alfalfa may be used to further upgrade forage production.

Cultivar Development and Improvement

The general objectives of our annual clover breeding program are (1) to develop varieties of winter-annual clovers with improved yield, forage quality, and insect and disease resistance; (2) to determine the inheritance of qualitative and quantitative characters; and (3) to develop improved breeding methods for specific species.

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2/ Underlined numbers in parentheses refer to items in "Literature Cited" at the end of this paper.

Most of the 250-300 species of *Trifolium* are annuals, and 15 or more of the annual clovers from the Old World contribute to forage production in the United States (23). Our program includes arrowleaf, berseem, *T. alexandrinum* L., crimson, and subterranean, *T. subterraneum* L., with major emphasis on crimson and subterranean.

Improvement of annual clover species has been through the use of the following methods or combination of methods (1) plant introduction and natural selection; (2) plant introduction, evaluation, and mass selection; (3) modified mass selection and recurrent selection; (4) inbreeding, polycross testing, and hybridization; (5) host plant resistance.

Crimson Clover

Most crimson clover cultivars were developed through natural selection for hard seed (11, 12, 19, 20). 'Dixie', a composite of three local reseeding strains in Georgia, was one of the first certified cultivars and accounts for most of the certified seed production today (11). The reseeding cultivars 'Auburn', 'Autauga', and 'Talladega' were developed through natural selection for hard seed. Disease resistance and a tendancy to produce hard seed were incorporated into 'Kentucky' and 'Chief' (4). 'Frontier' and 'Tibbee' were selected for seed size, seedling vigor, and early fall growth (14, 15).

The reseeding characteristic in crimson clover is associated with a moderately high percentage of hard seed (11, 12). These hard seed germinate gradually over a considerable period of time during autumn. This insures a stand, even though one or more earlier stands of seedlings may have been killed previously by dry weather after germination. Hard-seed content of a cultivar may vary from 30 to 75 percent. Apparently, this range in hard seed content is due to environmental conditions during seed maturation and to genetic factors. A water-soaking technique was used to successfully select hard-seeded lines. Several hard-seeded lines were combined to develop the cultivar 'Chief' (4). A 9-year regional test indicated that once high levels of hard seed were attained in a cultivar, the hard-seed characteristic is maintained in a population under the environment of the Southeast without successive reseeding generations (18). Recent work indicates that high-temperature-induced dormancy could be used as a second survival mechanism in crimson clover (16).

Seeds of reseeding cultivars frequently are scarified during harvesting and processing and may contain as little as 5 percent hard seed when planted. Seed of reseeding cultivars cannot be distinguished from that of common crimson clover, and use of certified seed is recommended to insure cultivar trueness. This is particularaly important with Oregon-grown seed since the common type behaves as the reseeding types under Oregon conditions.[3/]

Selection for general combining ability within and among selfed lines of crimson clover using polycrosses has produced uniform and especially virorous inbred lines. Regional evaluation of experimental double cross hybrids has confirmed inbreeding and hybridization as a successful means of combining inbred lines, each having desirable characteristics.

3/ Personal communication with Harold Youngberg, extension agronomist, Oregon State University, Corvallis, Oregon 97331.

Recurrent selection for resistance to seed shattering and to plant lodging has produced lines with approximately 20 percent greater seed retention and 30 percent less lodging than nonselected material. The percentage of hard seed has increased substantially with selection for nonshattering. Non shattering crimson clover should increase seed yields from 50 to 100 percent.

Seed weevils, _H_. _meles_ Fab., have caused a rapid decline in crimson clover acreage since 1960 (_19_, _20_). In preliminary host-plant resistance studies, wide differences were found in feeding preference of clover head weevils tested on crimson clover inbred lines (_26_, _27_, _28_). Resistance to the head weevil should increase seed production as much as threefold and enable farmers to capitalize on this important winter-grazing crop without chemical control of the weevil (_25_).

Arrowleaf Clover

Arrowleaf clover is a relatively new winter annual legume in the United States (_20_). Early selections were made in the 1930's from plants growing in uncultivated parts of central Italy. Several introductions of this clover to the United States were made in 1956 and grown at the Southern Regional Plant Introduction Station, Experiment, Ga. After being evaluated for forage potential, three cultivars were released (_3_, _13_, _17_). The major differences among the three are in lengths of growing season and time of maturity. 'Amclo', the earliest maturing cultivar, reaches full bloom in central Georgia by mid-May (_3_). 'Yuchi' blooms 3 to 4 weeks later than 'Amclo' while 'Meechee' blooms about 5 weeks later (_13_, _17_). When soil moisture is sufficient, the later-maturing cultivars are the most productive. 'Meechee' is the most winter-hardy of these three cultivars (_17_). Seed of the three cannot be distinguished from each other, so the use of certified seed is recommended to insure cultivar trueness.

Subterranean Clover

Extensive development with subterranean clover, _Trifolium subterraneum_ L., has been carried on in Australia where this species occupies 34 million acres and has a potential in that country of 100 million acres. Subterranean clover is also an important species in the Pacific Coast States of the United States.

Our work with subterranean clover has been primarily plant introduction and evaluation for adaptation (_21_). Sixteen varieties and experimental strains and 25 accessions of subterranean clover have been evaluated at Mississippi State, Miss. (_21_). Performance of five of the subterranean clover varieties grown alone and with ryegrass and fescue indicated adaptation and the great potential of this species in improving much of the grassland of Mississippi and the Southeast. Forage production of this species is approximately the same as for crimson clover and reseeding is assured through both hard seed and embryo dormancy. Estimates of forage quality remained high until maturity. Subterranean clover varieties were approximately 10 percent higher in soluble cell contents and 8 to 19 percent lower in cell wall constituents than ryegrass. Digestibility of ryegrass-clover mixtures and that of the clover component of the mixtures were similar. The decumbent runners of subterranean clover remained palatable and highly digestible. In addition to five cultivars that appear to be adapted in their present state, a number of the 25 accessions offer a wide range of available characteristics including morphology, maturity,

and insect and disease resistance. This material should provide a valuable source of germplasm in developing superior subterranean clover cultivars for Mississippi and the Southeast.

Minor Clovers

Berseem clover has more rapid fall growth than most annual clovers and recovers quickly following clipping. A wide range of plant characteristics is available through plant introduction. Selections have been found suitable for use in Florida by Kretschmer (22). Selection for winter hardiness in Mississippi has given a winter-hardy type which was increased from survivors of field temperatures as low as 5° and 8° F. These surviving plants were from the variety 'Sacromonte' introduced from Italy in 1970.

Persian clover, *Trifolium resupinatum* L., is widely adapted in the South. Producers' fear of bloat has caused this species to fail to reach its potential as a forage crop. A wide range of plant material, representing wide variations in maturity, forage yield, and recovery after clipping, is available through plant introduction (24). Weihing (30) applied selection pressure for hard seed to desirable agronomic types from three plant introductions to develop the improved, hard-seeded variety 'Abon'. Reluctance to use Persian clover should diminish with present knowledge and use of poloxalene blocks.

Priorities of Improvement by Species

Crimson:

(1) Develop resistance to the seed weevil.
(2) Improve reliability of reseeding.
(3) Develop resistance to virus diseases.
(4) Develop nonshattering types.

Arrowleaf:

(1) Develop more reliable early emergence.
(2) Improve spring and summer persistence.
  A. Develop virus resistance.
  B. Develop resistance to root diseases.
  C. Develop drought tolerance.

Subterranean:

(1) Develop reliable reseeding and persistent varieties in association with grass.
(2) Select for forage yield and distribution.
(3) Select for disease resistance.
  A. Develop virus resistance.
  B. Develop resistance to scorch (anthracnose).

Berseem:

(1) Select for winter hardiness
(2) Select for resistance to leaf diseases

Other Important Factors in Variety Development

Considerable improvement has been made in inoculation of clovers with specific Rhizobium strains. Cooperative research is needed between clover breeders, microbiologists, and soil scientists to improve the efficiency of the plant and the specific Rhizobium strains (1, 9, 29).

Additional information is needed on the soil fertility requirements of forage legumes particularly regarding minor element requirement. Molybdenum is recommended for soybeans in the Southeast but not for forage legumes. This could be a fruitful area of research (6).

Some method needs to be devised for the release and promotion of new cultivars whereby they can be sold at competitive prices and made available to the farmer in a minimum amount of time following release.

SUMMARY

The southeastern United States has the land and water resources for a thriving livestock economy. It is estimated that in Mississippi alone there are about 4 million acres of improved permanent pasture. Of this total, only 1 million acres has a legume growing in combination with grass.

An abundance of high-quality forage with good seasonal distribution is the foundation for cattle profits. Economical production of this high-quality forage is essential for the continued growth and success of the livestock industry. Labor and machinery costs involved in the production, handling, storage, and preservation of feed for livestock continually increase. Systems of year-round grazing that permit the animal to harvest most of the feed consumed should result in economical production of milk and beef. Economic analyses of grazing systems indicate that in the future an increased emphasis will be placed on the use of adapted clover cultivars in grazing systems. Proper use and management of annual clovers in these systems should result in large economic gains for the livestock industry in the Southeast. This will require more widespread use of superior cultivars already available, as well as others made available through future development.

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LEGUME MANAGEMENT

By R. E. Blaser [1]

Leguminous Plants in the Southeastern United States

Leguminous forage species have always been of great economic importance in the southeastern United States, and now the sharp increases in the costs of nitrogen fertilizer are causing a renewed interest in forage legumes. The low nitrogen, caused by the low recycling from low soil organic matter, is a major problem in plant nutrition. The improving of nitrogen fertility of soils is of practical significance for growth stimulation, improving the protein of grasses, and shifting the forage components to the best quality improved forage grasses. The high costs of nitrogen make it practical to amend soils with calcium, magnesium, phosphorus, sulfur, potassium, and trace elements when necessary to grow legumes for their value as forage and for the nitrogen they provide for associated grasses. Legumes in forage programs are very desirable because of the potential reduced cost of production, the better seasonable distribution of forage growth, and the better nutritional value for animal production than grasses.

Many annual and perennial legumes are adapted to the southeastern region. Perennial lespedeza and alfalfa are the longest lived perennials. Red clover varieties range from winter annuals to biennials to perennials with 3 productive years. White clovers behave as winter annuals in the lower Southeast and and short-lived perennials further north.

It is more difficult to grow legumes than grasses, and it requires much more management to grow legumes in monocultures or in association with grasses than to grow grasses alone. Grasses are tolerant of mismanagement and cover up our errors of judgement.

It is not generally practical to grow legumes alone in the southeastern region of the United States because of low yields, encroachment of weeds, short seasons of production, and animal bloat. Growing legumes with grasses makes such mixtures suitable for flexible utilization by cattle for grazing, silage, hay, or stockpiled forage.

Legumes of cool-season origin cause problems in management. The flush growth in spring in warm-season grass associations often causes animal bloat, and the subsequent flush summer growth of grasses crowds out legumes. This flush growth may provide more forage than is utilized during this time and the excess may revert to poor quality with much stemminess and many seedheads, causing low intake and digestibility by animals.

Objective management of grass-legume pasture should provide for the needed quality and supply of forage for animals and should consider the morphological and physiological characteristics of the plants. Although animal responses

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will not be considered here, this factor is of paramount importance, as forages are useless unless they are converted into products for humans.

Managing Legumes in Grass Associations

The management of legumes in monocultures or with grasses depends on the morphological and physiological characteristics of the species in legume-grass mixtures. First, we will analyze white clover management in grass associations, as varieties of white clover are used in the Southeast more than any other legume. Because white clover plants behave as annuals in the lower Southeast and as short-lived biennials or perennials in the upper Southeast, it is essential to manage pastures to get natural regeneration of seedling plants at the appropriate season each year. Where white clover behaves as a perennial because of rooted stolon proliferations, it appears that yields are substantially higher from new seedlings than from old plants. This is attributed to taproots that are deeper than the stolon roots of perennials. Depth of rooting is very important because all white clover varieties are morphologically small and shallow-rooted.

Generating New Seedlings of Winter Annual Legumes

Seedlings of 'Ladino' and other white clover varieties, as well as other annual legumes, are easily generated from year to year without soil preparation. In areas where white clover is almost entirely a winter annual, it is important to select varieties that seed prolifically during spring. Varieties from the long day environments of the more northern latitudes require long daylight periods to induce flowering and seed production.

In our early work in Florida, we found that white clover seed from the more northern latitudes of the United States and Europe failed to bloom and produce seed for regeneration because daylight hours were to short. Thus, adapted winter-annual white-clover varieties for the lower Southeast are those with prolific seed production during the relatively short days in spring. After the flush spring growth and seed production of white clover, the competition from warm-season grasses, disease, and other pests often exterminate white clover. Other winter-annual legumes, such as crimson and arrowleaf clover, die after seed production in spring.

The regeneration of a clover crop for the next fall to spring season depends on seedling development during late summer and early autumn. In Florida, we noticed that there was little or no germination of volunteer seed, which had fallen to the soil the previous spring, until November or later. Delays in clover germination delayed winter pastures; however, with September-October germination and early seedling development white clover is ready for grazing from January onward. A flush germination from volunteer seed occurred after a cool, frosty period, provided that the grass was closely grazed. No seedlings appeared in tall grass sods. On the other hand, we noticed that commercial white clover seed germinated at any season of the year.

Postulating that cool temperatures stimulated germination, we took small blocks of soil from white clover-grass pastures in late summer containing volunteer seeds of white clover from the previous spring and placed these in refrigerators at different temperatures. Cooling the soil for a few hours to temperatures in the range of 40° F caused a flush germination and fast seedling growth when later exposed to higher temperatures. Each succeeding cycle of exposure to a cool temperature followed by a higher temperature stimulated

germination. Seeds in the soil samples at room temperature in the 70° F range did not germinate. We also separated some of the volunteer clover seed from the soil; scarifying the seed coats with sandpaper and placing them in a moist environment caused swelling and germination at a wide range of temperatures. However, unscarified seed stayed hard and did not absorb water. Thus, cool temperatures in a moist soil in some way triggers water absorption by volunteer seeds with hard seed coats.

In early fall, we established an experiment on a dense grass canopy 8 to 12 inches high, where white clover seed had fallen to the soil the previous spring. Mowing very closely and removing the growth or burning off the accumulated grass caused excellent germination and subsequent stands of white clover seedlings. However, the dense and insulating sods prevented soil temperatures from declining enough to allow germination. Thus, very close grazing of grass sods during late summer to obtain reduction of soil temperature during cool spells for germination makes it possible to regenerate clover populations without expensive tillage.

Controlling the Grass-Clover Balance

When growing white clover with grasses of warm-season origin such as Dallisgrass and bermudagrass, it is generally impossible to control the amount of grass and clover in pastures. During the late autumn to spring season, the warm-season species grow slowly because of cool temperatures; hence, pastures are clover-dominant, especially during early spring. During the summer season, however, various diseases and insect pests plus competition for light from fast-growing grass canopies deter clover, causing grass dominance.

With cool-season grass and white clover mixtures, including such grasses as Kentucky bluegrass, orchardgrass, and tall fescue it is reasonably possible to control both grass and clover by judicious grazing management and fertilization. For bluegrass-white clover pastures at Rokeby Farm, a livestock and Thoroughbred horse farm in northern Virginia, we have maintained a good balance of grasses and white clover for 25 years without reseeding or tilling, using fertilization and grazing management.

Increasing white clover in bluegrass pastures is a two-step program. First, close grazing during the late summer to autumn season or during the spring months encourages germination and establishment of seedling plants, if they are not present. There are usually plenty of hard white clover seeds in the soil. Second, use needed soil amendments and employ grazing management that encourages growth of clover seedlings or the invasion of remnants of perennial white clover plants.

The encroachment of white clover into grassy pastures is related to management as interrelated with the morphological-physiological aspects of species *per se*. If growth of two species in a pasture is retarded by a given management, the species that is retarded the most will become subdominant. Conversely, if management practices stimulate growth but are relatively more favorable to the rate of growth of one species than to the growth of another, then the first species will become dominant. For any given species, the primary factors to be considered in planning a management program are leaf area (LAI), total nonstructural soluble carbohydrate reserves (TNC), and new shoot initiation. These factors in turn must be interrelated with changing environmental conditions, including pest incidence.

During the cool spring in which temperatures of both soil and air are low, grass growth is rapid as compared to white clover because cool season grasses grow better than white clover at low temperatures. Thus, early and close grazing of grasses reduces competition for light and encourages clover growth. Futhermore, grazing grasses closely causes very sharp LAI reductions because grass tillers tend to be erect. With such close grazing, the animals eat off some of the stubble, thereby consuming plant parts that are high in TNC. Thus, the combined effect of close grazing of grasses like bluegrass, tall fescue, and orchardgrass slows up the regrowth rate due to a low TNC and LAI.

However, such close grazing encourages white clover invasion for several reasons. All grazed leaves of white clover die, so new leaves and shoots develop at the base of the stolons at the soil level. Ruminants cannot graze the prostrate white clover stolons nor short prostrate leaflets; therefore, high light intensities at the soil surface coupled with the adequate TNC reserves under close grazing encourage clover invasion.

Under light spring grazing during the spring season the tillers with flower buds, initiated under the cool temperatures of short days during late fall and winter, begin to elongate. These flowering, erect stems of cool-season grasses give severe competition for light that is often lethal to the prostrate white clover.

A continuous heavy close grazing during the spring and autumn season when moisture is favorable increases white clover in canopies. However, very close grazing during drought periods in the summer is usually more adverse to the white clover than to the grass. White clover is subject to moisture stress because of its shallow roots, and extremely close grazing which exposes soil elevates temperatures and increases desication of white clover stolons. Such grazing during the summer is also very harmful to the cool-season grasses because the elevated temperatures depress photosynthesis, encourage high respiration, and deter cell division and expansion.

With 'Ladino' clover, continuous close-grazing management causes very low LAI's and depresses its growth and persistence. Thus, judicious rotational grazing in which the grass-clover canopies are allowed to reach a height of 6 to 12 inches and then grazed to sod residue of 1 to 3 inches is conducive to maintenance of a grass and clover balance. 'Ladino' tolerates judicious continuous grazing for several months during the spring, when moisture and temperatures are favorable for rapid growth.

For grasses such as 'Kentucky 31' tall fescue that are adapted to a wide range of moisture, temperature, fertility, and pest conditions, it is imperative to graze the sod closely to reduce competition for light and encourage clover survival and invasion.

Increasing the Grass Component

In situations where cool-season grass and white clover mixtures are clover-dominant and cause animal bloat, the grass component can be increased by nitrogen fertilization and grazing management. In this situation, it is imperative to practice lax grazing, especially during the spring and autumn seasons. Grazing no closer than 2 or 3 inches leaves a high LAI and TNC value for grasses, causing rapid regrowth of the grass canopy and causes a reduction in available light near the soil surface which inhibits leaf and shoot development of clover. Permitting the spring canopy growth to accumulate and cutting for hay or silage severely depresses white clover.

CONCLUSIONS

Under continuous grazing, sod residues strongly influence the botanical composition, quantity, and quality of forage. When rotational grazing is necessary, as with the tall, erect perennial species, management of the canopy involves many factors. Variable regrowth periods or rates of growth after grazing, determined by heights or stages of the regrowths influence the percentages of nonstructural carbohydrates in basal organs the leaf areas and the nutritional value of developing canopies when grazing is initiated. A rotational grazing period should be short, a few days to a week, especially while rapidly developing, erect shoots are easily defoliated. The stubble leaft after grazing should be controlled to encourage rapid regrowth from old or new shoots. For source species leaf area indices in grazed sods are related to light interception and rate of regrowth; for others soluable carbohydrates influence regrowth, and for others both soluable carbohydrates and leaf areas are important.

Within each of these three categories adjustments should be made for each species with allowances for flexibility, since growth rates vary with season. Management should provide for a grass-legume balance, high yields of desired forage quality, the best possible seasonal distribution of forage, and weed control, all with little or no mowing and other use of mechanical equipment.

LEGUME NUTRITION

By Grant W. Thomas [1/]

INTRODUCTION

The nutrition of legumes for forage is a difficult subject to cover both because of the lack of specific knowledge of the subject and because, in the case of most legumes grown in the South, there is a continuous competition between the legumes and associated grasses or weeds for sunlight, water and plant nutrients. Because of this competition, the successful nutrition of legumes uses strategy in which the legume must be favored so that the associated plants do not become too competitive. This paper attempts to outline this strategy under some of the existing soil and climatic factors found in the southern region of the United States.

Legumes are grown for forages because they provide nitrogen at a low cost. The advent of cheap nitrogen caused a drastic decline in the interest in, and acreage of forage legumes during the 1960's. The return of good old-fashioned expensive nitrogen, more than any other thing, accounts for this symposium.

The question in legume nutrition boils down to this: Can I produce and use nitrogen on the farm more cheaply and beneficially than I can buy it? The answer, when cheap nitrogen was available, was, all too often, no. Even with expensive nitrogen the answer may be no if legumes are considered as decorative additions to forage fields, rather than being used to their full potential.

Factors that Affect Nitrogen Fixation

There are three basic nutritional limitations to root growth and/or nitrogen fixation in legumes. The first is the presence of substantial amounts of aluminum (and sometimes manganese) in the soil solution. The second is the lack of or unavailability of molybdenum in the soil and the third is a lack of calcium in the soil. The third limitation (Ca) is rare. Enough work has been done on these problems so that fairly routine approaches can be used to cure them.

In the case of aluminum and/or manganese toxicity the root growth is severely inhibited and the cure is to lime the soil to between pH 5.5 and pH 6. This pH range gives nearly complete precipitation of aluminum and manganese and they cease to be problems. An example of this effect on alfalfa growth by Moschler et al. (1960) is shown in Figure 1. The loss of 80% of the exchangeable aluminum and attainment of 95% of maximum yield occurred at pH 5.7. Similar work on ladino clover by Shoop et al. (1961) showed a maximum yield at the point where exchangeable aluminum was reduced to about 0.1 meq/100g.

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There is no question that the largest effect of lime is to reduce aluminum and manganese toxicity. There also is no question that when this is done there will be ample calcium in the root zone to assure rapid root elongation (Adams, 1971). The effect of liming on molybdenum availability does not stop at pH 5.5-6.0, however. The deficiency of molybdenum is insidious and can be partially alleviated by liming up to pH 7. Reports of alfalfa responses to liming up to pH 7 can nearly always be viewed with the suspicion that the response was to molybdenum. A study by Giddens and Perkins, (1960, Fig. 2), shows this very well as does a study by Dawson and Bhella (1972) on subterranean clover in Oregon (Fig. 3). Eventually, however, even the high pH soil is apt to run out of molybdenum if cropping is continued (Giddens and Perkins, 1972, Fig. 4). Therefore it is a cheaper approach to lime to a reasonable level and add a small amount of molybdenum.

The specific problems ennumerated here are those that must be cured before legume growth can be assured. Aluminum and manganese precipitate on the surfaces of roots and hinder water and nutrient uptake. Calcium deficiency stops root growth altogether and molybdenum is directly required in the nitrogen fixation reaction.

Effects of Nitrogen Fixation on the Legume

There are three profound effects of nitrogen fixation on the legume, one is beneficial and the other two are very nearly suicidal. The beneficial one, of course is the availability of nitrogen in such quantities that it is never a limiting factor in growth.

The first suicidal effect is caused by the fact that all fixed nitrogen is in the reduced form and that hydrogen ions equivalent to the fixed nitrogen are released to the soil (Nyatsanga and Pierre, 1973). The effect is exactly the same as that found when nutrient solutions containing ammonium are used (Dodge and Hiatt, 1972). Thus legumes tend to befoul their environment by excreting the acid that will eventually result in their death unless liming is practiced.

The second suicidal effect is that when legumes are cut, grazed or frosted, they shed roots which then decompose and release nitrogen which is taken up by grasses and weeds. The nitrogen allows the grasses and weeds to compete more vigorously for sunlight, water and plant nutrients. This effect is the same as that found when fertilizer nitrogen is added to a grass-legume mixture (Table 1). This table also shows that addition of nitrogen to grass-legume sods is always a losing proposition.

TABLE 1.--Effect of nitrogen addition on the yields of orchardgrass and ladino clover.

	N rate (lbs. per acre)			
	0	80	120	160
	Yields of forages (lbs. per acre)			
Orchardgrass	3100	4200	5200	5000
Ladino clover	4200	3000	2500	2100
Total	7300	7200	7700	7100

It ought to be clear by now that legumes grown in association with grasses lead precarious lives, and that some of the problem is associated with nitrogen fixation by the legumes themselves.

Competition between Legumes and Grasses for Potassium

Although a great deal has been written about the competition for potassium between grasses and legumes, very little really is known. The classic study by Blaser and Brady (1950) has been quoted very widely and misquoted even more widely. It showed that on a soil that was initially very low in potassium, a mixture of weeds, grasses and ladino clover took up potassium in that order. Addition of potassium increased uptake by grasses and weeds but did not increase their yield since they were already adequately supplied. The added potassium did increase the yield of ladino clover, however, since the potassium supplied by the unfertilized soil was inadequate for clover growth.

The implications of the study by Blaser and Brady are clear. Legumes do not compete very well with grasses or weeds for potassium when the soil potassium is low. There have been many reasons advanced for this behavior such as cation-exchange capacity of roots and the effect of a fibrous vs. a tap root system (neither of which explains why weeds are better than grasses in potassium uptake). What does appear to be the case is that starch and/or sugar storage is closely tied to potassium supply in the root crops (Jackson and Volk, 1968) and that legumes used for forage can be thought of as root crops. What little competitive advantage legumes have is based on their large storage of energy in the root. This, in turn is sensitive to potassium content of the plant which is hard to maintain when (1) soil potassium is low and, (2) grasses and weeds are present. The obvious strategy to employ is the addition of potassium when the legume needs it most. The competitive effect for potassium is much less in the spring than in the summer and fall (Table 2). Therefore, it follows that the time to apply potassium is not in the spring but during the summer. Then, there will be a more efficient use of the applied potassium.

TABLE 2.--Potassium percentage in ladino clover, grass and weeds as affected by potassium rate and time of year.

	% K in plants					
K_2O rate (lbs/A)	Ladino		Grass		Weeds	
	May	Oct	May	Oct	May	Oct
0	1.91	0.50	2.16	1.31	2.53	1.79
75	2.23	0.76	2.87	1.75	3.05	2.12
150	2.75	1.03	3.27	2.12	3.59	2.73

More recent studies have shown that the original observation of Blaser and Brady are correct. Table 3 shows data from a Virginia experiment on alfalfa and orchardgrass (Blaser and Kimbrough, 1968) where the potassium additions to the Lodi soil needed to be quite high to supply alfalfa adequately.

TABLE 3.--Effect of potassium rate on percentage potassium in orchardgrass and alfalfa.

	% K in plants, lodi loam	
K_2O rate (lbs/A-yr)	Orchard grass	Alfalfa
0	2.71	0.70
40	3.46	1.21
80	4.01	1.78
320	3.85	3.53

Critical Levels of Potassium in Legumes

Although it is generally recognized that legumes have rather high potassium requirements, partly because of the competitive relationship described above, the critical levels have been almost impossible to determine. Values in the literature range from 0.8 to 4.0%. Considerable light has been shed on this problem by Kimbrough et al. (1971) who showed that on a whole plant basis, the potassium level required for optimum growth changed drastically with age at cutting. However, this does not appear to be the whole story. Unpublished data by Wells and Vaught, University of Kentucky, (1972) showed no yield response in alfalfa when potassium varied from 4.0 to 1.3% from first to fourth cutting even though each cutting was taken at the same age. The values for the first and fourth cuttings are shown in Figs. 5 and 6.

It appears that a realistic value is around 2% averaged over the whole year. It is likely that this is too low for early cuttings and too high for later cuttings.

Phosphorus Needs of Legumes

The phosphorus requirements for legumes are usually discussed as though the exact amounts needed in both plant and soil were well known. Such is not the case because phosphorus requirements for legumes depend so strongly upon the treatment they receive and upon what competition they have.

A very interesting study in California was carried out by Jones et al. (1972) in which subterranean clover was clipped one, two, three and four times. The critical levels of phosphorus were 0.11, 0.18, 0.23 and 0.28%, respectively at 120 days. The results of the entire study are shown in Table 4. This indicates that the high phosphorus levels usually associated with legumes are required only if they are used hard. This probably is associated with the need for high phosphorus for rapid regrowth after cutting. If phosphorus is low and rapid regrowth does not occur then it is likely that grass and weeds will regrow faster and shade the legume.

Phosphorus levels required for alfalfa probably are in the neighborhood of 0.25 to 0.40% depending on the competition and weather conditions. Lutz (1973) found no difference in alfalfa yield when phosphorus levels were 0.30 and 0.37 one year but a more than two-fold increase when phosphorus increased from 0.21 to 0.42 in another. Wells and Vaught (Unpublished Data, University of Kentucky, 1973) showed very little difference in alfalfa yield averaged over a year with phosphorus levels ranging from 0.30 to 0.40%, but at the last cutting a change from 0.27 to 0.35% gave a slight response.

TABLE 4.--Effect of plant age and number of clippings on the critical phosphorus level of subterranean clover.

Critical levels of P in sub clover (% P)				
Plant age (days)	No. of times clipped			
	1	2	3	4
48	0.52			
77	0.34	0.42		
107	0.15	0.19	0.27	
120	0.11	0.18	0.23	0.28

The approach to phosphorus nutrition seems to be to keep the soil level high and hope that the legumes will take it up. If the forage is to be grazed or cut heavily this is particularly important. If it is not to be used heavily, phosphorus is not so important. Of course in this case it is not necessary to have legumes in the first place.

Sulfur Needs for Legumes

The reguirements of legumes for sulfur are really no different than for grasses; they are related to the nitrogen content of both. Any higher sulfur requirement for legumes is related to a higher nitrogen level which usually occurs in legumes. A fairly good relation is a nitrogen:sulfur ratio of 15:1 by weight. This also is true of grasses. Thus a legume containing 3% nitrogen should contain 0.20 sulfur, and one containing 4% nitrogen should contain 0.27% sulfur.

The more common occurrence of sulfur deficiency on legumes as compared to grasses is based on the lower nitrogen contents and lower sulfur removal of grasses. When coastal bermudagrass was heavily fertilized with nitrogen and removed as hay, sulfur deficiency showed up on the second cutting (Landua et al., 1973) in a sandy east Texas soil.

Probably the most pressing sulfur research needs in the South are a reevaluation of sulfur dioxide in the air and rainfall (the last was done 20 years ago) and a systematic sampling of forages from different soil areas. Some of the latter work is now being done.

Rooting Characteristics of Legumes vs. Grasses

The roots of alfalfa are popularly supposed to grow deeper than those of grasses. This idea is based pretty much on the work of Weaver (1926) with alfalfa. There has been little work done on this problem, particularly in the South, but it appears that soils exert more effect than plant type on rooting characteristics.

Weaver worked on the deep, uniform soils of Nebraska which tend to be somewhat dry for adequate plant growth and thus encourage deep root growth. A water removal study on a deep limestone soil in Kentucky showed that alfalfa removed water in about the same way as did corn and bluegrass. Nearly all the water came from the surface 3 ft. (Table 5, Karraker and Bortner, 1939).

TABLE 5.--Inches of water removed from Maury silt loam by corn, bluegrass-white clover and by alfalfa in the drouth year of 1930 (Karraker and Bortner, 1939).

	Inches of water used per foot of soil		
Depth (ft.)	Corn	Bluegrass-White clover	Alfalfa
1	2.52	2.84	2.62
2	1.80	2.20	2.02
3	1.05	1.50	1.05
4	0.50	0.52	0.68
5	0.10	0.01	0.35
6	0.00	0.06	0.22
Total	5.97	7.13	6.94

Part of the reason that bluegrass is thought to be a very shallow-rooted crop is that when cut or grazed short it is. An old study by Sprague and Graber (1938) showed that during the summer bluegrass cut weekly used only one-third as much water as that allowed to grow for 65 days without cutting. Alfalfa used only half as much water when cut weekly as when allowed to grow for 65 days. Yields were cut in half for alfalfa and to one-tenth in bluegrass when weekly cutting was practiced (Table 6).

TABLE 6.--Effect of clipping on yield and water use in alfalfa and bluegrass.

		Yield	H_2O/D.M.	H_2O Used
Alfalfa	65 days	26.91	505	13,583
	weekly	12.97	608	7,883
Bluegrass	65 days	10.82	713	7,716
	weekly	1.16	1,939	2,250

As nice a myth-destroying study as can be found was done by Lamba et al. (1949) in Wisconsin. They found that type of soil had a profound effect on the rooting depth of both alfalfa and bromegrass (Table 7). Even in the soil in which alfalfa rooted most deeply, most of the roots were in the top two feet. The root distributions (by weight) of alfalfa, red clover and bromegrass grown in Miami soil are shown in Fig. 7. The root length distribution is shown in Table 8 and shows the grass to be a better proliferator of soil even at considerable depth.

TABLE 7.--Depth of alfalfa and bromegrass roots in three soils.

Soil	Alfalfa	Bromegrass
	Root depth (inches)	
Miami	75	42
Spencer	22	24
Plainfield	48	--

TABLE 8.--Root length of alfalfa, red clover and bromegrass with depth, Miami silt loam.

Depth (in.)	Miles of roots per acre		
	Alfalfa	Red clover	Bromegrass
0-8	890	839	11,850
8-16	333	379	7,760
16-24	408	617	6,420
24-32	475	--	7,310

These few observations on rooting characteristics indicate that more needs to be done on the following points. (1) Water removal vs. depth; (2) Nutrient removal vs. depth; (3) Effect of soil characteristics on rooting pattern, and (4) Effects of cutting and grazing on root growth with depth. It is about time that we took a renewed interest in root growth and quit accepting Weaver's old pictures as the Gospel.

SUMMARY

1. Aluminum (and Maganese) must be low for normal root growth.
2. Molybdenum must be available for N-fixation to occur.
3. A pound of fixed nitrogen makes the soil just as acid as a pound of applied nitrogen does.
4. Addition of nitrogen to a grass-legume mixture accomplishes nothing in total yield and lowers legume yield.
5. Grass and weeds compete strongly with legumes for potassium - especially late in the season.
6. Potassium is needed for reserve storage in the legume roots.
7. The critical level of potassium is not known. Early and young it is higher than later and older.
8. The critical level of phosphorus depends on whether legume is cut and the plant age.
9. The sulfur requirement is about 1/15 of nitrogen for both legumes and grasses.
10. We need to understand the effect of management (cutting and grazing) on the root system and resultant nutrient and water uptake by legumes on many important soils.

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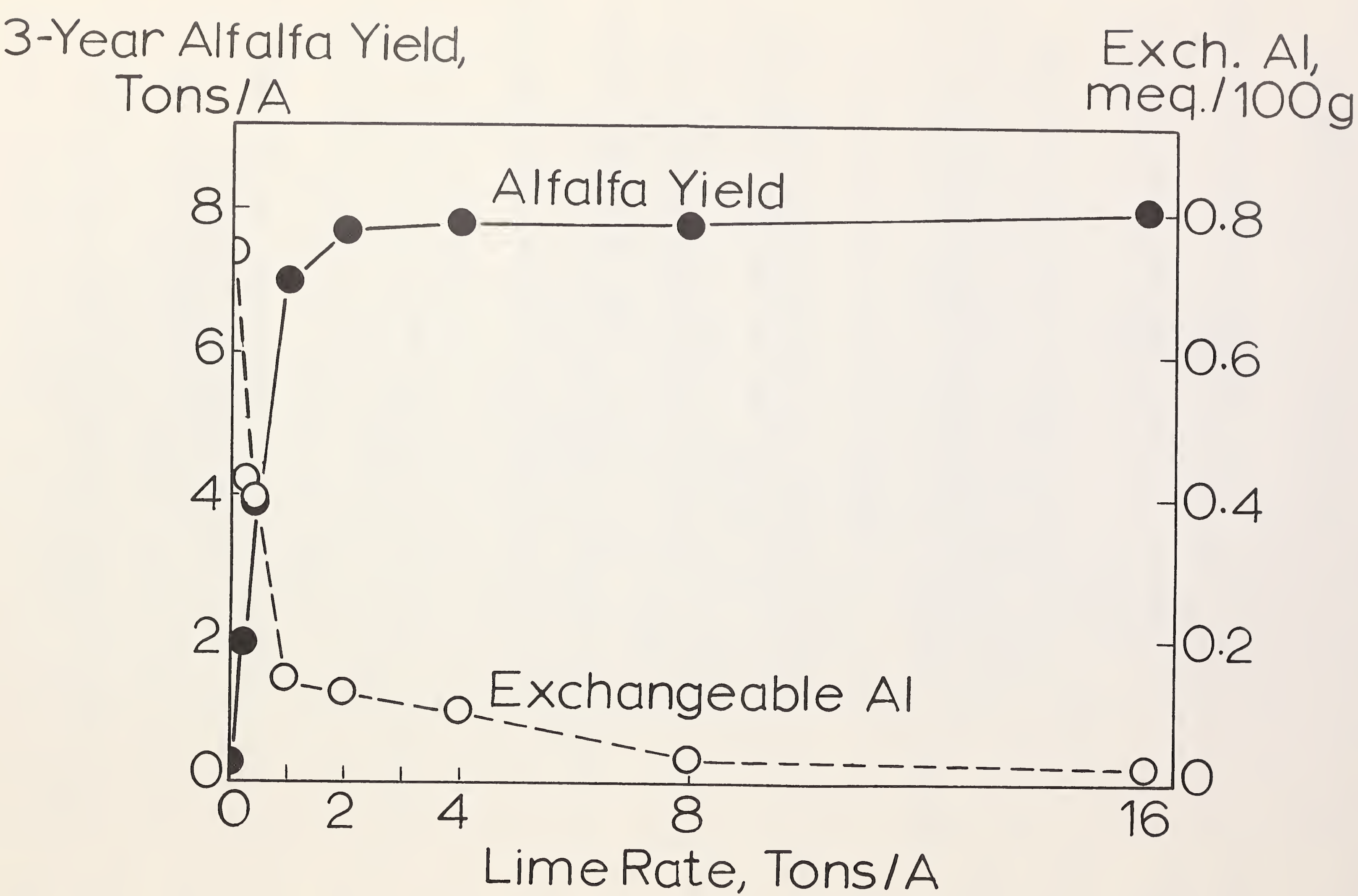

Fig. 1. Effect of lime on alfalfa yield and exchangeable aluminum content of Tatum soil.

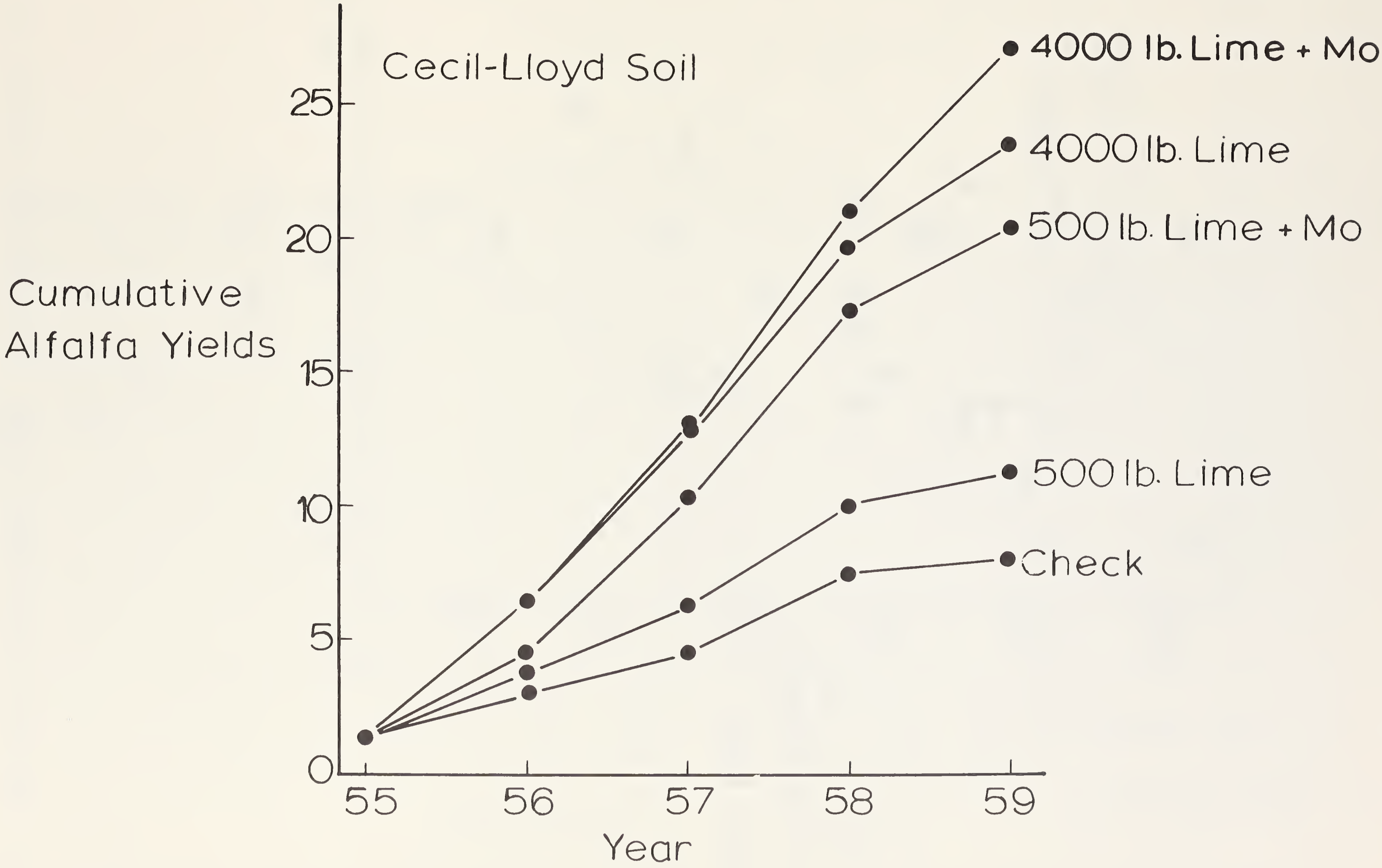

Fig. 2. Effects of lime and molybdenum on cumulative yield of alfalfa.

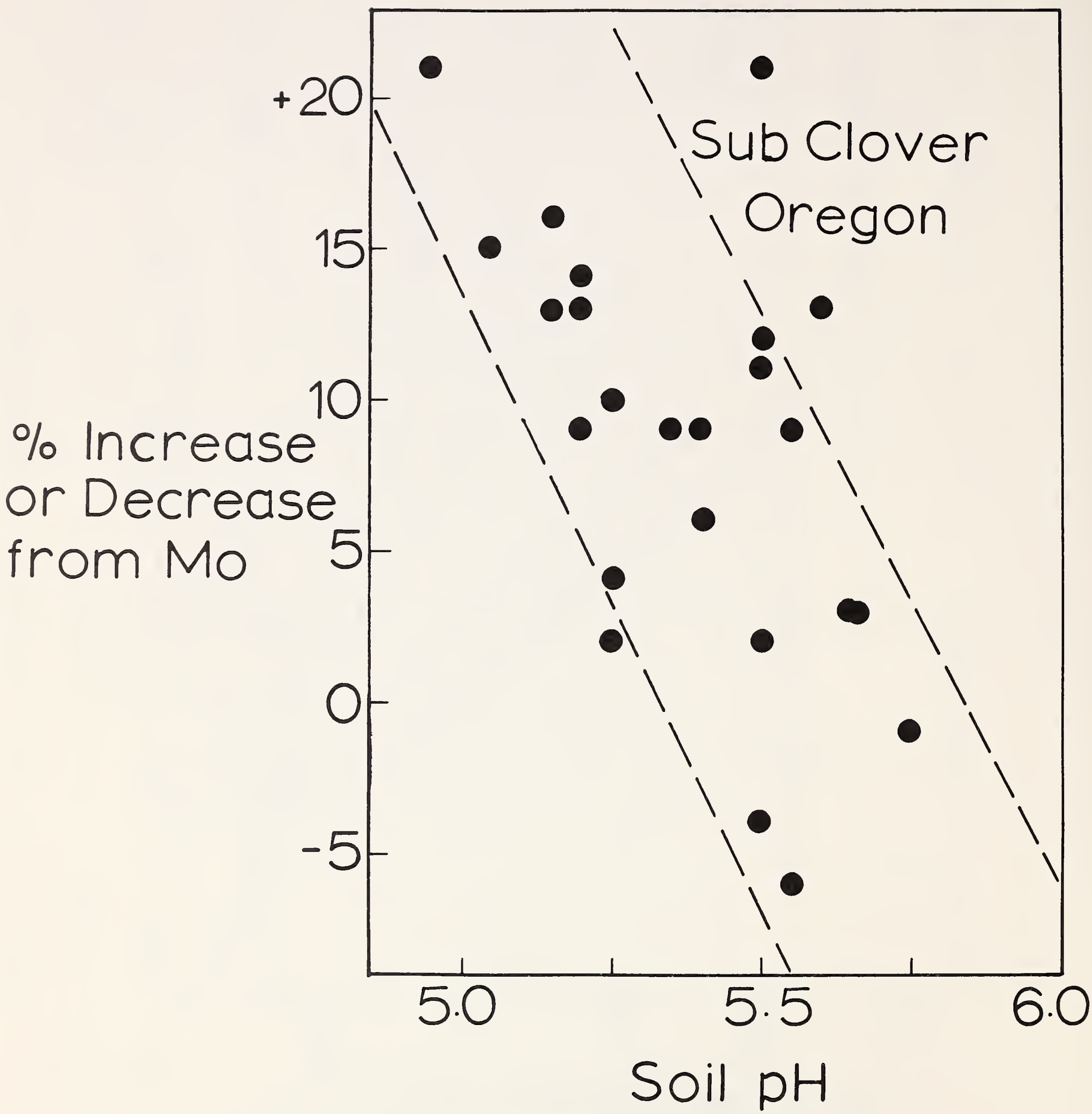

Fig. 3. Response of subterranean clover to molybdenum at different soil pH levels.

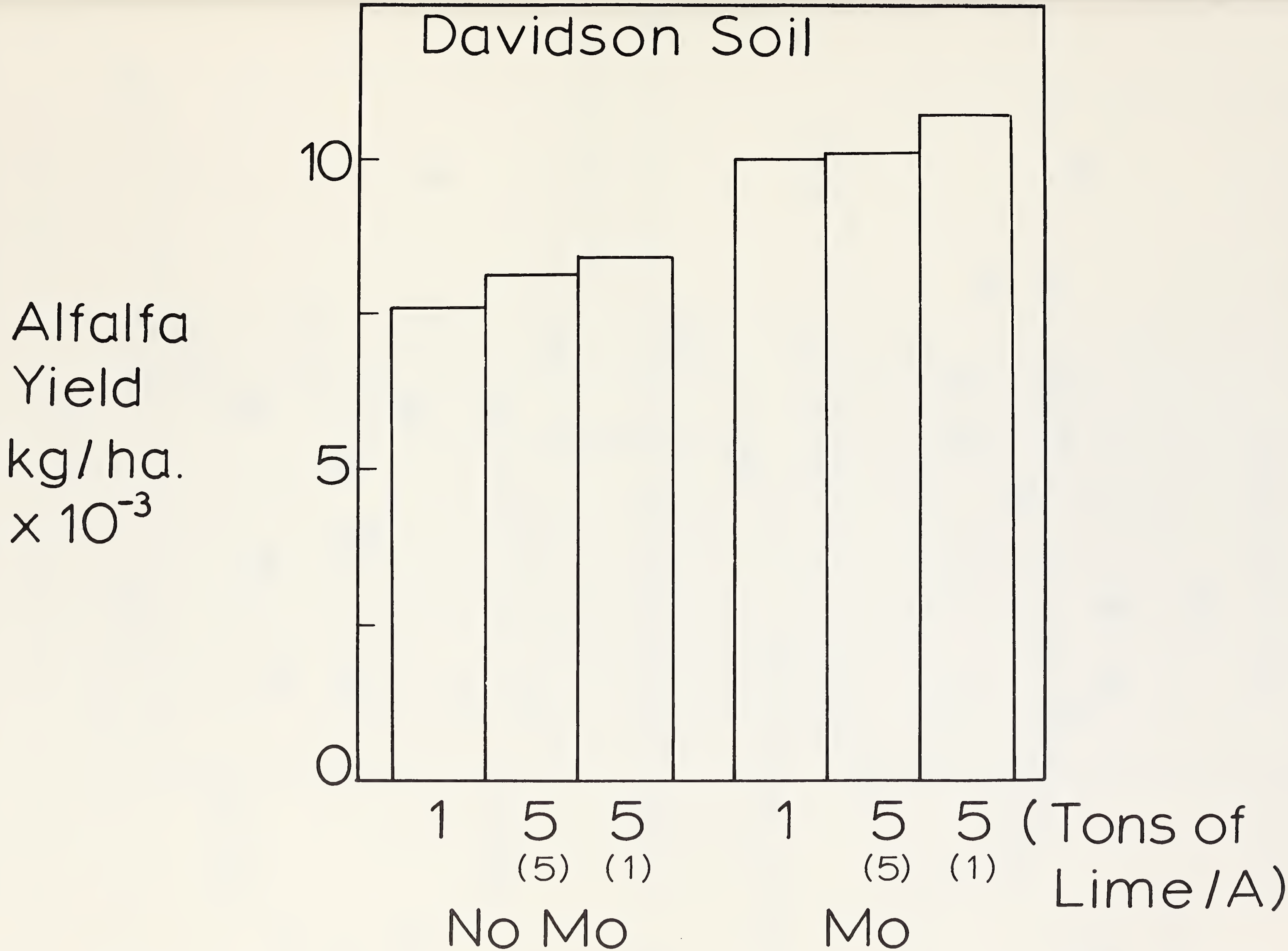

Fig. 4. Effects of lime rate and molybdenum on alfalfa yield (5) indicates 5 tons of lime in 5 yearly applications and (1) indicates 5 tons of lime in one application.

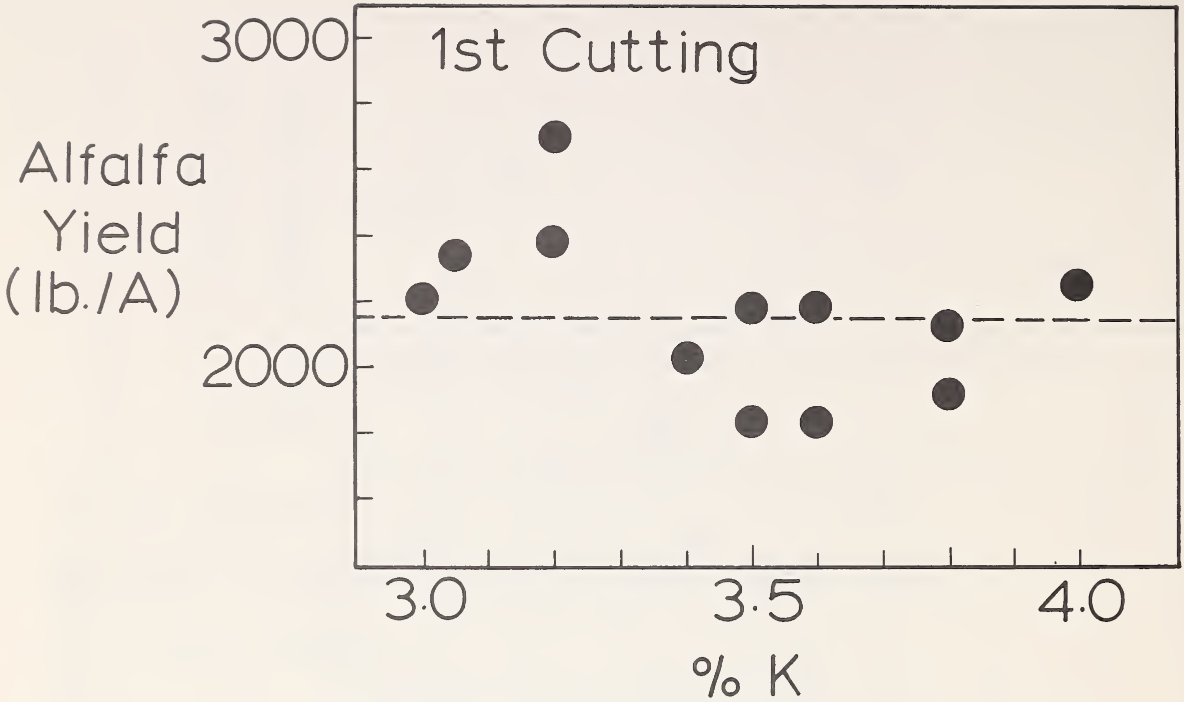

Fig. 5. The effect of potassium percentage in alfalfa on yield (first cutting).

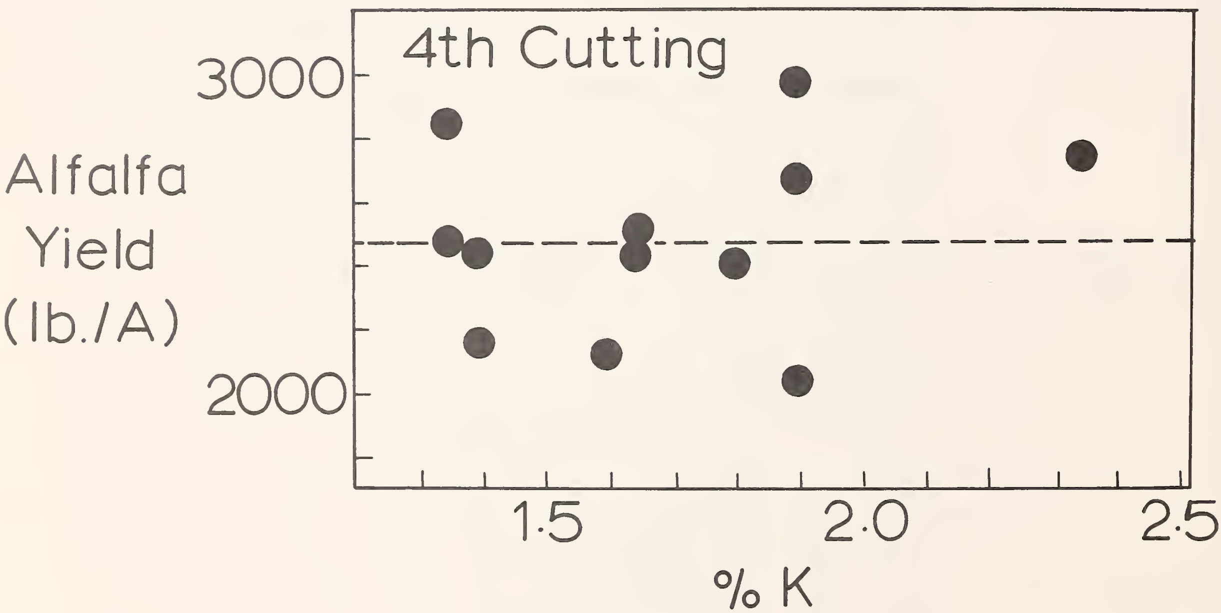

Fig. 6. The effect of potassium percentage in alfalfa on yield (fourth cutting).

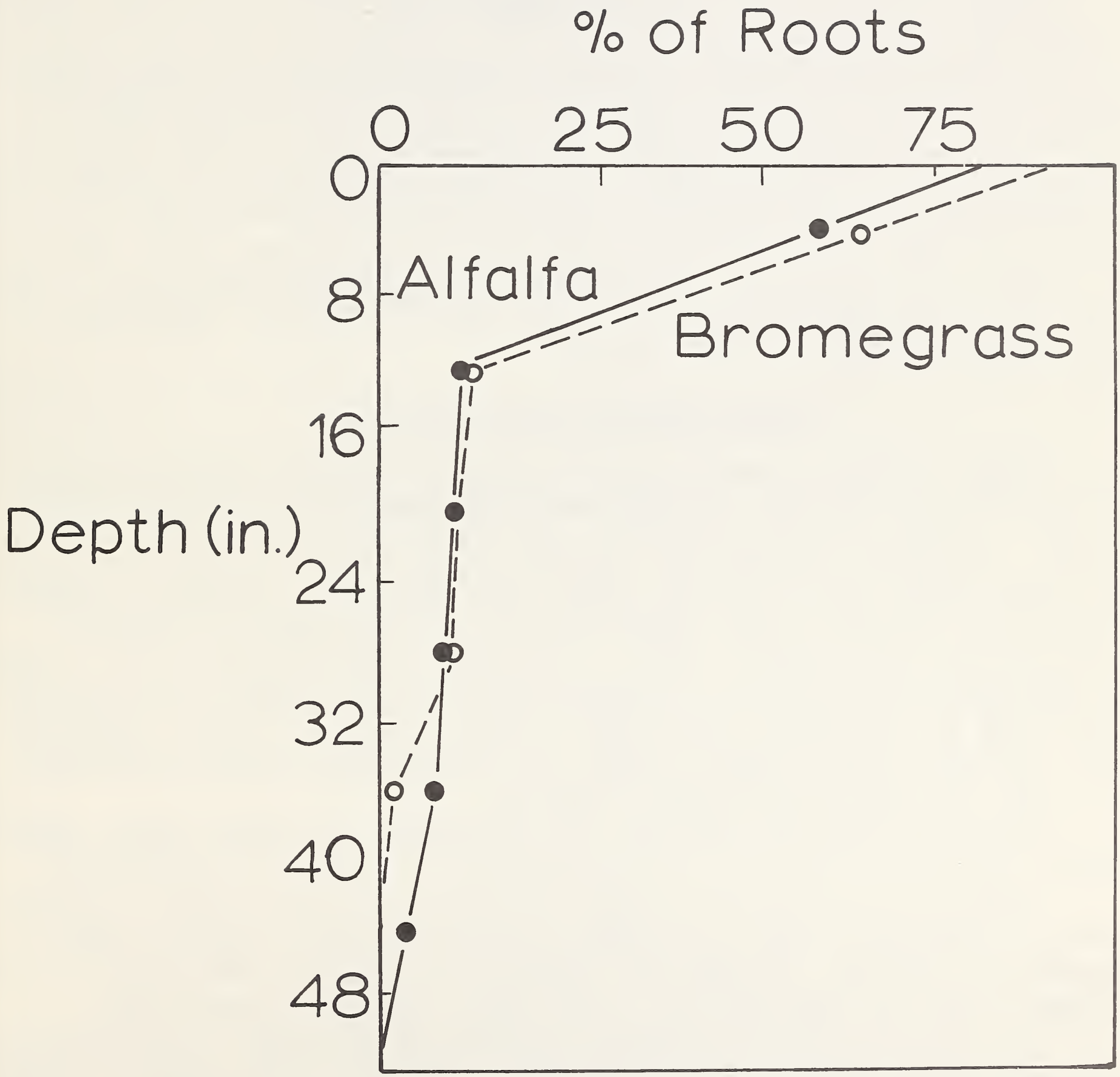

Fig. 7. Distribution of alfalfa and bromegrass roots in a Miami silt loam soil.

PRODUCING LEGUME SEED

By Harold Youngberg [1/]

INTRODUCTION

Oregon is a major source of legume and grass seed for the United States. Oregon produces more than 90 percent of the United States perennial reygrass, annual ryegrass, and bentgrass seed, more than half of its orchardgrass and fine fescue, and significant amounts of bluegrass and tall fescue. Legume-seed production is very compatible in this area of concentrated grass seed production as a rotation crop and to utilize equipment more efficiently. Oregon grows more than 90 percent of the United States crimson clover seed, 12 percent of its red clover, and 7 percent of its alfalfa seed.

Mechanical quality and genetic purity are emphasized, as these fields are grown solely for seed and return is assured only by producing a marketable, high-quality product.

Trends in General Seed Production

The price-supply situation of 1973 and early 1974 was a combination of several long-term factors. A buyers' market has existed in seeds for a number of years. Large carryover stocks have kept prices near cost-of production levels. In response, growers have reduced acreage of those crops in which they were least competitive or in which prices were depressed. In 1973 the dollar devaluation stimulated export demand, and the carryover began to disappear. Substitution of seed began to affect other species and stimulated large price increases late in the season. These price shifts would normally have increased the acreage of seed crops, but this influence has been moderated by promise of high prices for alternative crops such as wheat. There has been no widespread shift from seed crops to wheat, however, but farmers have planted fields that were ready for rotation from seed production.

Increased production costs for fuel, fertilizer, equipment, labor, taxes, and interest have stimulated careful evaluation of returns from seed production.

Open burning of straw following grass-seed harvest has become a standard practice. Burning provides quick and economical disposal of residues from perennial seed fields. Several other important results have been noted — disease, insect, and weed control coupled with a seed-yield stimulation. Currently, a legislative ban prohibiting burning after January 1, 1975, is in effect because of the air pollution resulting from the burning. Major efforts are underway to find alternative practices that provide the benefits of burning without the accompanying air pollution. It appears that any solution will increase costs of grass-seed production.

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Legume seed crops are grown without burning residues. The imposition of a burning ban or a phase-out program will stimulate interest in adapted legumes as problems associated with grass-seed production increase. This will be of particular importance in the clovers because of shifts from grass seed to clover seed.

Trends in Legume Seed Production

Oregon produced 6.7 million of the 99.8 million pounds of alfalfa seed grown in the United States in 1973, 2.3 of the 2.7 million pounds of crimson clover, and 3.4 million of the 28.8 million pounds of red clover. Figures on white clover are not available, but production was estimated to have been in excess of 1 million pounds. Production of hairy vetch remains at 2 million pounds, and interest in common vetch is slight.

Oregon certification statistics indicate some trends in clover production (table 1). 'Dixie' crimson, 'Kenland' red, and 'Louisiana S-1' have been popular because of known yields and demand. Seed yields and returns from arrowleaf clover has not been encouraging, resulting in limited production.

TABLE 1.--Oregon clover certification statistics

Clover	Acres of production 1972	Acres of production 1973
Arrowleaf:		
'Amclo'	--	50
'Meechee'	20	69
'Yuchi'	72	--
Crimson:		
'Dixie'	819	917
Red:		
'Kenland'	2,331	705
'Lakeland'	188	43
'Pennscott'	396	220
White:		
'Grasslands huia'	44	178
'Louisiana S-1'	1,312	955
'Merit'	216	16
'Tillman'	256	197

Crimson clover production peaked in 1970 at 7.9 million pounds (table 2), and the national supply (production plus carryover) reached 12.3 million pounds, or about double the annual disappearance. As a consequence, the price to the seed grower was severely depressed and has remained depressed. Some price recovery was noted in 1973 and in preplant contracts for the 1974 crop, but not enough to reverse the downward acreage trend. The crop outlook for 1974 is estimated at a low of 1.7 million pounds. Estimates of production costs for crimson clover are $184 per acre (table 3). At the 400-pound state-

yield average for crimson clover, the grower would need a price of $0.46 per pound to meet his costs (table 4). Acreage of crimson clover would be stimulated by offers of 38 to 42 cents per pound for 1975 production.

TABLE 2.--Crimson-clover seed production in Oregon

Year	Production (100,000 lb)	Average Season Price/Cwt
1969	6.1	$22.00
1970	7.9	11.80
1971	2.9	13.60
1972	2.0	20.00
1973	2.3	2/
1974	1.7 1/	2/

1/ Estimated.
2/ No average computed.

TABLE 3.--Production costs per acre of crimson clover grown in Oregon in 1974

Production Item	Cost
Seed and Fertilizer	$20.00
Custom Spraying	15.00
Machinery	24.50
Labor	7.50
Seed Cleaning and Testing	30.00
Land Tax and Interest	83.00
General Overhead	3.00
Total	$183.00

TABLE 4.--Production cost per pound with varying yields of crimson clover, 1974

Yield/acre (lb)	Cost/lb
200	$0.91
400	0.46
600	0.30
800	0.23

Arrowleaf clover-seed production has been evaluated in western Oregon, and recommendations for seed production have been published. Erratic seed yields, possibly resulting from its season of growth, coupled with harvest difficulties, have been discouraging. Prices 10 to 15 cents over the prices for crimson clover would be required to stimulate increased production. Price competition from the Southeast apparently prevents an attractive price in the

Pacific Northwest.

Expanded production of white clover is very likely. Lack of supply of foundation seed of certain improved varieties has limited their certified seed production, but this situation has been corrected with certain varieties. Improved weed control techniques have also enhanced production possibilities. White clover offers an alternative on some soils that are now growing grass seed but may be affected by the field-burning ban. Winter losses may reduce yield and hold 1974 prices near 1973 highs, but expanded production is likely in 1975 and later.

Red clover suffered from drought conditions in 1974 and pushed grower prices upward from $0.50 to $1.10 per pound. Prices in 1974 are expected in the 75-85 cent range. Red clover is grown in many rotations, and production will continue in this area.

Oregon alfalfa seed production is concentrated in the eastern and northeastern parts of the state. The national alfalfa production in 1973 was 5 percent below 1972, and the production plus carryover was down 11 percent from a year ago. Present prices have stimulated interest in increased acreage. Sales of foundation-seed stocks have indicated a reversal in the downward trend in acreage, but the impact of this shift may not be felt until 1975. The 1974 supply of alfalfa will depend on weather conditions affecting this season's crop. Increased production is expected, but higher prices are predicted.

CONCLUSIONS

Oregon seed producers supply seed of certain crops for many areas in the United States. In the last year or two, the supply demand relationship has changed and resulted in seed shortage and higher prices. In these times of adjustments in supply and needs, it is important to maintain the best possible communication between grower and consumer through all possible channels.

BREEDING WHITE CLOVER

By Pryce B. Gibson [1/]

INTRODUCTION

We believe in white clover (Trifolium repens L.) and work with it because it is the most important pasture legume in the South. It is the leader in total acreage and in quality of forage. A clover-grass pasture is superior to grass alone. A comparison of analyses of white clover and 'Coastal' bermudagrass on a dry-weight basis illustrates the relative quality of clover to grass and explains the superiority of clover and grass over grass alone.

Component	White clover: 'Coastal' bermudagrass
Crude protein	About 2:1
Digestible protein	About 2:1
Neutral detergent fiber	Less than 1:3
Nitrogen-free extract	About 6:1
Ether extract	About 3:1
Ash	Over 2:1
SiO_2	Less than 1:2

Clover also contributes nitrogen, which stimulates the growth of the grass. The energy shorthage has increased the importance of this contribution. We not only believe our work is justified; we believe the support of research on this valuable crop should be increased.

Current Research

For several years, the majority of white clover research in the United States has been carried out in the South. Six of the Southern States have white-clover improvement projects. The size of projects varies from a fraction of a scientist-man-year (SMY) to approximately 2 SMY. In addition to publicly supported work, the largest individual commercial producer of white clover seed in the world is located in the region. This producer follows a management system designed to cause a selection pressure for maintaining the characteristics of the clover he sells.

The improvement programs have the common long-range objective of increasing the persistence of white clover stands in clover-grass pastures. Secondary or immediate objectives include resistance to diseases, better root systems, and other factors that may contribute to improved persistence of stands and

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improved distribution of production.

Developed Cultivars

The success of the three cultivars released by the improvement programs of this region indicates the accomplishments of the programs. The combined annual acreage planted to the three popular varieties is by far the majority of white clover planted in the region. The varieties are:

'Louisiana S-1' -- Developed in Louisiana. Seed production is largely by seed producers in Louisiana and nearby states. Northwest United States also produces seed.

'Regal'----------- Developed in Alabama. Seed production is largely in California.

'Tillman'--------- Developed cooperatively by the South Carolina Agricultural Experiment Station and U. S. Department of Agriculture. Seed production in Northwest in cooperation with National Foundation Seed Project.

Hybridization

The three varieties mentioned are classified as synthetic varieties. A synthetic variety is synthesized by hybridizing in all combinations a relatively few elite clones that have been tested for combining ability. Seed production of the variety is accomplished by successive seed increases of no more than four generations from the parent clones. 'Louisiana S-1' and 'Regal' each have five parent clones, 'Tillman' has six. Thus, more and more of our white clover traces back to a few plants. This situation is of interest to those who are concerned about the vulnerability of our plant germ plasm.

Variation

White clover is a variable species, and this variation is available to the plant breeder. Size of the plant is a good example of the variation in the species. Plants vary from the small wild white one which may be only a couple of inches high to the large 'Ladino' which may be knee-high. Variation of other characters may be difficult to recognize or measure. For example, resistance to viruses is difficult to identify and measure.

Alien Germ Plasm

A second source of variation is alien germ plasm, germ plasm of other species. For the past few years we, in our program at Clemson, S. C., have concentrated on this source of variation. We have made progress, and we believe the possibilities of improving white clover by utilizing species hybrids justify a comprehensive program. We now have hybrids that offer changes in length of internodes, size of seed, depth and woodiness of roots, and disease resistance. In an effort to increase the chances of hybrids contributing to improved varieties, we have distributed hybrids to various locations including South Africa and England.

Sparsely and Profusely Flowering Varieties

All research has challenges and problems that require decisions. In 1972, at the 29th meeting of this conference, I discussed in detail the problems concerned with breeding white clover. The complete discussion is printed on pages 76-80 of the Proceedings for the 29th Southern Pasture and Forage Crop Improvement Conference. Probably the problem of most general interest or controversy is: "Should we develop an improved variety that flowers profusely and produces a good yield of seed, or should we develop an improved variety that produces few flowers and seed in our area?" Unfortunately, more is involved than flowering and seed production. For example:

(1) Sparcely flowering varieties produce more forage.
(2) Sparcely flowering varieties persist longer as perennials.
(3) Sparcely flowering varieties are more competitive with grasses.
(4) Sparcely flowering varieties give a better distribution of forage.

Because of these and other reasons, we have concentrated on sparcely flowering white clover. Counting the breeding work at other locations, over half of the total white-clover breeding effort is directed toward developing improved varieties of white clover that produce a seed crop in this area.

In the past, we have taken the stand that the extra 25 percent or more forage produced by the sparsely flowering varieties justifies, if necessary, annual sowing of seed on the pasture. Roy Blaser reports good results from this practice in Virginia. We hope more management projects will evaluate this practice. Regardless, profusely flowering white clover has advantages. For example, as far as we know, virus diseases of white clover are not transmitted through the seed. Therefore, volunteer clover seedlings are virus-free until visited by a viruliferous vector. Seed can be produced in the South. The importance of this characteristic depends upon policies of western seed producers. If a stand is lost, ample seed is in the soil to produce a new stand when conditions become favorable for germination.

Virus Resistance

In our opinion, the greatest advantage of reseeding varieties is starting with virus-free plants once a year. However, virus resistance is a better solution to the problem. O. W. Barnett at Clemson University, Clemson, S. C., and L. T. Lucas at North Carolina State University, Raleigh, are clarifying the virus problem in white clover. Erroneous identifications of viruses affecting white clover in the past have delayed progress. For example, a few years ago because of improper identification Bean Yellow Mosaic was mistakenly reported to be a major disease of white clover.

We now know that resistance to the important viruses that attack white clover exists in the species. Resistance to the viruses can be incorporated in an adapted variety. However, it will take time. Species hybridization offers a second source of resistance to the viruses. *Trifolium ambiguum* is resistant to all the important viruses. Also, it has rhizomes, a character that may improve presistence of white clover. Since *T. ambiguum* is taxonomically close to white clover, hybridization may be possible.

Regardless of the source of resistance utilized, we believe virus-resistant varieties will be developed and will replace the varieties now being grown.

DEVELOPING NEW ALFALFA VARIETIES FOR THE SOUTH

By Thad H. Busbice 1/

INTRODUCTION

Currently, there are about 1.3 million acres of alfalfa being grown in the South. Slightly more than half of this acreage is in Oklahoma and Texas. Most of the remainder is in Arkansas, Tennessee, Kentucky, and Virginia. Because of increasing demand for a cheaper source of protein feed for an expanding livestock industry, alfalfa production in the South will probably triple within the next few years, providing that seed of better adapted varieites can be made available to the region.

Alfalfa is not considered to be well-adapted to the warm, humid areas of the world. This lack of adaptation has been attributed largely to susceptibility to insects and diseases, but other factors relating to adaptation are also involved. Alfalfa has never been subjected to long period of natural selection in warm, humid areas, and breeding programs in these climates are relatively new.

Presently, there are active alfalfa-breeding projects at four locations in the South, in Fayetteville, Ark. in Gainesville, Fla.; in Raleigh, N. C.; and in Blacksburg, Va. These projects have participated in the development and release of the cultivars 'Victoria', and 'Florida 66', 'Cherokee', 'Team', 'Apalchee', 'Arc', and 'Williamsburg'. 'Cherokee', 'Team', and 'Williamsburg' have been widely grown in the South, and 'Cherokee' has now become extinct. 'Victoria', 'Florida 66', 'Apalachee', and 'Arc' are new, and seed of these cultivars has not yet become available to most farmers. The seed production of 'Florida 66' has been stopped, and the line is undergoing further improvement. The emphasis of all these breeding programs is to develop cultivars adapted to local conditions and resistant to a multiple of insects and diseases.

Resistance to Alfalfa Weevil

Much more alfalfa was being grown in the South in the 1950's, before the spread of the eastern alfalfa weevil, than is grown today. The weevil, which has spread throughout the South, has devastated alfalfa production. Without the use of insecticides, total defoliation has occurred in many fields in the spring, reducing yield and stand life. Field selection for resistance to the weevil has been conducted in North Carolina with considerable success (table 1). 'NCW21', 'NCW20', 'Team', and 'Arc' are selections from a common germplasm source we call "Starnes." This is the only source of germplasm in which we have observed weevil tolerance, but it is also the only source in which we have practiced continued field selection.

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TABLE 1.--Percent of defoliation of alfalfa entries by alfalfa weevil larvae, during peak damage period of heavy natural infestation on land trial-seeded September 14, 1973, at 20 pounds of seed per acre in Raleigh, N. C., with subsequent yield of May 8, 1974

Entry	Percentage of defoliation	Yield (tons/acre)
'NCW21'	10	0.95 1/
'NCW20'	14	.91 1/
'Team'	20	.84
'Arc'	20	.82
'Weevlchek'	42	.68
'Cherokee'	46	.64
'Victoria'	52	.55
'Apalachee'	52	.55
'Williamsburg'	62	.48
'Kanza'	80	.41
LSD 2/	10	.19

1/ The more weevil-resistant entries 'NCW21' and 'NCW20' were growing out of the weevil damage at the time of harvest.

2/ Least significant difference at 0.05 level.

The first-harvet yields of NCW20 and NCW21 shown in table 1 were reduced by more than one-half ton of dry matter per acre by larval feeding. However, these experimental varieties have enough weevil tolerance to allow the avoidance of insecticides without damage to the stand, if the farmer chooses to accept the yield loss. In many fields, weevil damage on these cultivars would be minimal. I believe that a very high level of alfalfa-weevil resistance will be possible through breeding.

Resistance to Anthracnose

The discovery of anthracnose-disease resistance in alfalfa[2/] and the development of easy methods of selection for resistance[3/] have led to a major breakthrough in adapting alfalfa to the humid South. Within the last 4 years we have converted most of our breeding strains to anthracnose-resistant strains, and the cultivar 'Arc' has been released as the first cultivar highly resistant to anthracnose disease. Apalachee has an intermediate level of anthracnose resistance, and this resistance apparently was developed through passive field selection. Anthracnose disease has been a major limiting factor in alfalfa production in the humid South, and resistance has contributed significantly to both yield and persistance (table 2). In the humid South, new cultivars carrying resistance gene should persist 2 additional years and annually produce an

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2/ Barnes, D. K., Ostazeski, S. A., Schillinger, J. A., and Hanson, C.H. 1969. Effects of Anthracnose (*Colletotrichum trifolii*) infection on yield stand and vigor of alfalfa. Crop Sci. 9: 344-346.

3/ Ostazeski, S. A., Barnes, D. K., and Hanson, C. H. 1969. Laboratory selection of alfalfa for resistance to anthracnose. *Colletotrichum trifolii*. Crop Sci. 9: 351-354.

additional ton of hay per acre, as compared to the older, susceptible varieties. Cultivars carrying both anthracnose-disease resistance and improved weevil tolerance should make a very favorable impact on alfalfa production in the South.

TABLE 2.--Anthracnose damage of alfalfa entries, measured on September 6, 1973, and subsequent 1973 yield, on land trial-seeded on March 15, 1972, at 20 pounds of seed per acre in Salisbury, N. C.

Entry	Percentage of stand remaining	Yield/ (tons/acre)
Anthracnose-resistant cultivars:		
'NCW20'----------------------	88	5.6
'NCW18'----------------------	85	5.2
'Arc'1/----------------------	88	5.2
'Saranac AN4'----------------	83	5.3
'Vernal AN4'-----------------	88	5.4
'Glacier AN4'----------------	88	5.5
Average	87	5.4
Anthracnose-susceptible entries:		
'Apalachee'------------------	79	5.1
'Team'-----------------------	59	4.1
'Cherokee'-------------------	65	4.3
'Weevlchek'------------------	72	4.2
'Saranac'--------------------	58	4.4
'Vernal'---------------------	68	4.4
'Glacier'--------------------	48	4.2
Average----------------------	64	4.4
LSD2/	12	.5

1/ Breeding for anthracnose resistance in these entries was conducted by the Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Md.

2/ Least significant difference at 0.05 level.

Further Developments

Through the efforts of many people over a long period of time, we now have sources of genetic resistance to many insects and diseases. Important to the South, we have sources of resistance to the alfalfa weevil, pea aphid, spotted aphid, potato leafhopper, stem nematode, root-knot nematode, anthracnose, *Stemphylium* and common leaf spot, bacterial wilt, and *Phytophthora* root-rot. We are encouraged by our effeots to obtain *Sclerotinia* resistance. One of our objectives has been to combine all sources of resistance into a few well-adapted varieties.

Of interest is Victoria and other experimental lines developed for crossing tap-rooted and creeping-rooted alfalfa strains. Plants of these lines characteristically have a heavy, much-branched root system which is distinctly

different from the tap root characteristic of most alfalfa. The branching-root system may be important in the development of alfalfa for grazing and for the adaptation of alfalfa to the coastal plains of the South.

Over the years we have had repeated difficulty in getting prompt seed increases of new cultivars for the South because there were delays in getting foundation seed produced, due to too little expected profit by the seedsmen in producing for a limited and untried market, and to a lack of information reaching the seedsman concerning new cultivars. To overcome these difficulties, the breeder may have to assume more responsibility for the production of foundation seed, and limited, exclusive rights to the cultivar may have to be granted to certain seedsmen for a limited period to assure the seed producer of a profit potential.

RED CLOVER BREEDING

By Melvern K. Anderson and Norman L. Taylor [1]

INTRODUCTION

Red clover, Trifolium pratense L., is one of the most widely grown of all the true clovers. It is used mostly for hay and pasture, fits well into crop rotation systems, and is also useful in soil improvement. The two most active breeding programs at land-grant institutions in the United States are at the University of Wisconsin, Madison, Wis. (R. R. Smith, USDA) and at the University of Kentucky in Lexington. We will discuss our work at the University of Kentucky and then briefly mention the main features of the work at the University of Wisconsin.

Kentucky Program

Our major objective, to which all aspects of our program relate, is the development of more persistent, high-yielding cultivars of red clover. Two, possibly three, different approaches are being used in the development of these superior cultivars. Conventional breeding methods traditionally used in forage-crop breeding, such as mass selection and polycross progeny testing, were used to develop 'Kenstar', a newly released cultivar. It is expected that Kenstar will replace 'Kenland', an open-pollinated red clover cultivar, released cooperatively by the Kentucky Agricultural Experiment Station, Lexington, Ky., and the USDA in 1947. Kenstar is a 10-clone synthetic cultivar selected for greater persistence under Kentucky conditions than is available in Kenland and other cultivars.

Stands of Kenstar under optimum management have lived for 3-4 years, counting the year of seeding as the first year. Kenstar is similar to Kenland in general appearance, resistance to southern anthracnose and powdery mildew, and area of adaptation. The 10 clones are maintained vegetatively to reconstitute the cultivar as seed is needed. Breeder, foundation, and certified seed are being increased in Kentucky, and foundation and certified seed in the West. The effective release date was September 1, 1973. In addition, we are trying to generate improved synthetics by backcrossing improved disease resistance into the 10 I_0 parent clones of 'Kenstar'. We are trying to incorporate greater powdery mildew resistance and Bean Yellow Mosaic virus resistance, working with Steve Diachun and Lawrence Henson, Department of Plant Pathology at the University of Kentucky in anticipation that these synthetics will show greater persistence. Incorporation of mildew resistance has proceeded through backcrossing; intercrossing with selection of clones showing homozygous resistance, by mass-screening of the progenies; and polycross increase of seed from

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the 10 selected mildew-resistant clones. Bean yellow mosaic virus resistance has also been backcrossed into the I_0 clones, and intercrossing with selection and eventual increase of polycross seed will follow. Some difficulty is being encountered in infecting plants for screening due to continued backcrossing for bean yellow mosaic virus resistance. It appears that some of the 10 parent clones whose polycross progenies compose 'Kenstar' may already have a type of resistance which inhibits infection and thus the screening process.

In addition, we are continually looking at our synthetics in regard to class and seed source tests. We have several cooperative experiments with C. S. Garrison, USDA, which should provide a better understanding of the relationship between persistence and class of seed and location of seed production.

Several European reports have indicated that tetraploid red clover has increased disease resistance, persistence, or dry matter yield. We have produced a tetraploid synthetic comparable to 'Kenstar' so that exact comparisons can be made of genotypes at the diploid and tetraploid levels. Nitrous oxide has provided an excellent method of doubling chromosomes. Populations that are approximately 70 percent tetraploid have been produced by treating them 24 hours after pollination.

We are also involved in developing double-cross hybrid red clover varieties. Genetic control of crossing to produce a true double-cross hybrid is accomplished by the one-locus, gametophytic-incompatibility system. In essence, the procedure for producing a double cross hybrid involves (1) selfing I_0 clones to obtain I_1 progenies; (2) selecting agronomically desirable I_1's which are homozygous for _S_-genotype; (3) increasing desirable I_1's by vegatative or seed-increase schemes; (4) producing two single crosses from four selected and increased I_1's; and (5) blending single-cross seed for sowing to produce double cross hybrid seed.

We have produced a number of double-cross hybrids to date. Most of these were produced to ascertain the effectiveness of genetic control of crossing by the gametophytic incompatibility system. Many of the double crosses were similar to improved synthetics such as 'Kenstar' in performance. However, we felt that one double-cross did hold some potential, and in 1972 we produced with C. S. Garrison of the USDA about 4 kilograms of double-cross hybrid seed at Prosser, Wash. In the spring of 1973, this hybrid was sent to 26 locations in 17 states for testing.

In addition to these two specific breeding programs, we are also attempting interspecific hybridization with several perennial _Trifolium_ species to introduce desirable characteristics. The only successful interspecific hybrids with red clover to date have been with the annual species of _Trifolium_, _T. diffusum_ and _T. pallidum_. We have attempted to cross _T. medium_ with red clover and have used high-termperature treatments (40° C) on the female parent in conjunction with the attempted interspecific hybridization. We found the high-temperature treatment of no benefit, at least in crosses of _T. medium_ with red clover. It is hoped that with an increased understanding of interspecific incompatibility barriers, we can eventually obtain characteristics such as increased longevity from some of the perennial species of _Trifolium_. Several interspecific hybrids between perennial species not involving red clover have been successful in this past year.

Approximately 175 of the 250-300 _Trifolium_ species are maintained at this experiment station. We have obtained chemotaxonomic data as well as somatic chromosome numbers on many of these species. Our chemotaxonomic data on species' relationships as a predictive value of successful interspecific hybridization looks very promising.

Wisconsin Program

The major objective of the breeding program at Wisconsin is also persistence. However, persistence here refers mainly to the ability to overwinter and not the ability to withstand heat and water stress as in the Southern clover belt. This program also includes extensive investigations to try to improve resistance to powdery mildew, northern anthracnose, target spot, bean yellow mosaic virus, red clover veinal mosaic virus, and alfalfa mosaic virus.

Investigations are also underway to determine the effectiveness of various breeding methods used with hybrid red clover. In addition, stability parameters have been investigated to determine the extent of genotype and environment interactions.

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